UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
4. PERFORMING ORGANIZATION REPORT NUMBER(S)	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION Naval Postgraduate School 6b. OFFICE SYMBOL (*If applicable*) OR	7a. NAME OF MONITORING ORGANIZATION Naval Postgraduate School
6c. ADDRESS (*City, State, and ZIP Code*) Monterey, CA 93943	7b. ADDRESS (*City, State, and ZIP Code*) Monterey, CA 93943-5006
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Naval Postgraduate School 8b. OFFICE SYMBOL (*If applicable*)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (*City, State, and ZIP Code*) Monterey, CA 93943	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. | PROJECT NO. | TASK NO. | WORK UNIT ACCESSION NO.

11. TITLE (*Include Security Classification*)
An Approximation for Computing Reduction in Bandwidth Requirements using Intelligent Multiplexers

12. PERSONAL AUTHOR(S)
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13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (*Year, month day*)	15. PAGE COUNT
Master's thesis	FROM______ TO______	March, 1993	85

16. SUPPLEMENTARY NOTATION
The views expressed in this paper are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

17. COSATI CODES			18. SUBJECT TERMS (*Continue on reverse if necessary and identify by block number*)
FIELD	GROUP	SUB-GROUP	Telecommunications; model; stochastic telecommunications model

19. ABSTRACT (*Continue on reverse if necessary and identify by block number*)

This paper stochastically models a single-node telecommunications system both with and without the use of intelligent multiplexing. Intelligent multiplexers take advantage of the idle periods or silences that occur during the course of speech transmissions to merge (or multiplex) packetized talkspurts from more than one source onto a single channel. This allows for a more efficient use of available bandwidth, thereby reducing the amount of bandwidth required to carry a particular traffic load. Digitizing speech into packets of equal size also allows for compression, further reducing bandwidth needs. By comparing the models for systems both with and without multiplexing, we are able to determine the reduction in bandwidth which may be expected for a particular grade of service (measured by blocking probabilities). A bivariate continuous time Markov chain model for a multiplexer is presented. An approximation is introduced to calculate limiting blocking probabilities much more quickly and for larger systems than is possible by solving a set of linear equations for the bivariate model. The accuracy of the approximation is explored through comparison with the bivariate model; the approximation provides a somewhat conservative estimate of blocking, but is close enough to be used as a tool for the range of relevant values. The approximation is then used to compare blocking probabilities for three different levels of speech activity. Results are shown in tabular form.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT [x] UNCLASSIFIED/UNLIMITED [ ] SAME AS RPT. [ ] DTIC USERS	21. ABSTRACT SECURITY CLASSICIATION UNCLASSIFIED
22a. NAME OF RESPONSIBLE INDIVIDUAL P. Jacobs	22b. TELEPHONE (*Include Area Code*) (408) 646-2258 2c. OFFICE SYMBOL OR/Jc

DD Form 1473, JUN 86 *Previous editions are obsolete.* SECURITY CLASSIFICATION OF THIS PAGE

S/N 0102-LF-014-6603 UNCLASSIFIED

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An Approximation for Computing Reduction in Bandwidth Requirements using Intelligent Multiplexers

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MASTER OF SCIENCE IN OPERATIONS RESEARCH

From the

NAVAL POSTGRADUATE SCHOOL
March 1993

ABSTRACT

This paper stochastically models a single-node telecommunications system both with and without the use of intelligent multiplexing. Intelligent multiplexers take advantage of the idle periods or silences that occur during the course of speech transmissions to merge (or multiplex) packetized talkspurts from more than one source onto a single channel. This allows for a more efficient use of available bandwidth, thereby reducing the amount of bandwidth required to carry a particular traffic load. Digitizing speech into packets of equal size also allows for compression, further reducing bandwidth needs. By comparing the models for systems both with and without multiplexing, we are able to determine the reduction in bandwidth which may be expected for a particular grade of service (measured by blocking probabilities). A bivariate continuous time Markov chain model for a multiplexer is presented. An approximation is introduced to calculate limiting blocking probabilities much more quickly and for larger systems than is possible by solving a set of linear equations for the bivariate model. The accuracy of the approximation is explored through comparison with the bivariate model; the approximation provides a somewhat conservative estimate of blocking, but is close enough to be used as a tool for the range of relevant values. The approximation is then used to compare blocking probabilities for three different levels of speech activity. Results are shown in tabular form.

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THESIS DISCLAIMER

The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

I. INTRODUCTION

The field of telecommunications has been advancing at a tremendous rate in recent years, assisted by the decreasing costs and increasing capability of microprocessors, as well as by deregulation of the industry. New products and capabilities are coming online at an astounding rate. It has become commonplace to transport data between computers with the use of modems along standard telephone lines at ever-increasing baud rates. More companies every day are opting to use video-conferencing as a replacement for time-consuming travel to business meetings. Fax machines are now priced for use in the home as well as in the office. Cellular phones for use in automobiles and airplanes make "getting away from it all" more difficult than ever. The latest sensation to hit the consumer market is a telephone with video screen to view the person on the other end of the phone line (if they have the same device, of course), also priced for home use. There seems to be no limit to the potential market for increasingly sophisticated (i.e. bandwidth intensive) telecommunications products.

In order to provide economical transmission of high bandwidth data, such as fax and video, it has become increasingly important to find inexpensive ways to increase bandwidth and to conserve the bandwidth available. A variety of technical innovations, such as fiber optic networks, data compression techniques, and multiplexers, have been developed to do just that.

A. WHAT IS MULTIPLEXING?

Multiplexing techniques are designed to reduce bandwidth needs, thereby reducing costs, by sharing bandwidth among network users. Intelligent multiplexers accomplish this by sending the packetized information from a large number of channels onto a single wideband channel, without transmitting any of the silent periods. This achieves very high utilization rates along the single channel.

Intelligent multiplexers take advantage of the idle times that occur during the course of any telecommunications transmission to make more efficient use of available bandwidth. Speech conversations, for instance, are silent about 60% of the time; when one person is speaking, the other is normally silent and listens. Also, there are pauses between words and sentences. Data traffic often averages only 5-15% efficiency, tending to be bursty, occurring for a short time, then subsiding to occur some undetermined time later. These bursts of data traffic also have high bandwidth requirements.

There are two basic types of intelligent multiplexer on the market. The older of the two is referred to as statistical time-division multiplexing (STDM) or statistical packet multiplexing (SPM); the newer is called fast packet multiplexing (FPM). They are both microprocessor-based, meaning both higher efficiency and higher cost when compared with frequency division multiplexing and time division multiplexing. These newer technologies will consequently only begin to replace what is already in use as microprocessor price/performance ratios improve enough to justify the efficiency gains.

B. STANDARDS

Due to the current lack of standards for intelligent multiplexing equipment, manufacturers have each designed their own intermachine communication systems, and no two systems are compatible. This creates problems when users of private networks want to tap into another private or public network. It can also make direct comparisons among various vendor products difficult for the potential buyer.

Standards bodies, such as the American National Standards Institute (ANSI), the International Telegraph and Telephone Consultative Committee (CCITT), and the Institute of Electrical and Electronic Engineers (IEEE), are working on standards for equipment which will likely supersede current multiplexer technology. Standards seem to be evolving in the direction of transmitting all information (speech, data, video, etc.) in the form of packets or "cells."

C. DEFENSE COMMUNICATIONS AGENCY INTEREST

The Defense Communications Agency (DCA) is extremely interested in exploring the capabilities of these new and emerging technologies in order to plan ahead for changes to MILDEP networks. Studies are ongoing to assess the various intelligent or "smart" multiplexer products on the market and to determine criteria on which to base future purchasing decisions [Ref. 1: pp. 1-23].

In the Advanced Design Group, headed by Dr. Martin Fischer, the inclusion of intelligent multiplexers (smart mux or smux) will affect the network topology design tools currently being developed. The key question for them, regarding the smart mux, is how much of a reduction in bandwidth

can be obtained by the use of intelligent multiplexers while maintaining current network performance levels. Their data base contains bandwidth costs based on AT&T tariffs as well as the cost data for several different brands of multiplexer. They also know how many channels are required to carry a particular traffic load, expressed in Erlangs, without the use of a smart multiplexer. A simple way to calculate the reduction in channels needed when multiplexers are added to the network would allow them to do comparative cost analyses.

D. PURPOSE OF THIS STUDY

The purpose of this study is to find a simple, yet relatively accurate, way to determine the reduction in bandwidth which will result from adding intelligent multiplexers to a voice network. It will involve stochastically modeling a single node of a communications network, both with and without a multiplexer. Approximations to the more complicated stochastic model are then studied.

In the next section we provided a summary of the technology. In Section III we review some of the relevant literature. Section IV presents a description of the models studied, while Section V covers the approximation techniques used to compute limiting probabilities for those models. In Section VI we describe the programs used to perform the calculations and the validation techniques for the computer code. In Sections VII and VIII we discuss the numerical results and conclusions, respectively.

II. DESCRIPTION OF THE TECHNOLOGY

A. FREQUENCY DIVISION MULTIPLEXING

The oldest multiplexing technique is frequency division multiplexing (FDM). FDM divides the frequency spectrum of analog circuits into smaller narrowband segments. The narrowband implementation limits the data rates which can be used for remote networking [Ref. 2: p. 54].

B. TIME DIVISION MULTIPLEXING

Time division multiplexing (TDM), which began to replace FDM when remote network data rates increased above 2400 bits per second (bps), divides the communication link into a fixed number of time slots. Each slot is assigned to a specific channel. Transmission occurs in a regular sequence, cycling through the channels. Bandwidth allocation is fixed, and is based on the size of the time slot allocated to each channel. TDM is relatively inexpensive to implement and introduces very little delay. However, TDM is not very efficient in the use of bandwidth. If a channel is idle, that time slot is not available for use by any other channel. Also, the silent periods of a voice or data transmission go unused. For combined voice and data traffic, TDM averages only 10-25% efficiency. TDM is unable to momentarily increase bandwidth for high-speed data due to the fixed time slots and bit rates. Thus, TDM is not well-suited to transporting a dynamically varying combination of voice, fax, and LAN traffic [Ref. 2: p. 54].

C. STATISTICAL PACKET MULTIPLEXING

Statistical packet multiplexing solves both of the problems associated with TDM, that is, network efficiency and ability to dynamically allocate bandwidth, but has two drawbacks of its own. It introduces higher network delay and difficulty in predicting the amount of delay. Thus, SPM is not suited for time-sensitive information, such as voice and video traffic.

Instead of statically dividing the network bandwidth as in TDM, SPM dynamically allocates bandwidth to those channels passing data at the moment. Within the multiplexer (mux), SPM operates by gathering transmitted data from the active channel into a packet, appending identifying and control information, and passing the packet to the next multiplexer. The next mux checks for transmission errors (using the control information) and requests retransmission if errors are found. Any errors are corrected before the packet is sent on. The packetization of data also allows the originating multiplexer to easily perform various operations on the data, such as encryption and compression.

Due to the different advantages and disadvantages associated with both TDM and SPM, many networks in use today are hybrids that combine the two. TDM is used for time-sensitive information (voice, video, some synchronous data and LAN traffic) while SPM is used where higher network efficiency and dynamic bandwidth allocation are important (primarily asynchronous data, and some synchronous data and LAN traffic) [Ref. 2: p.55].

Descriptions of the first three multiplexing techniques may be found in references [Ref. 2: pp. 54-55, Ref. 3: pp. 112-113, and Ref. 4: pp. 165-188].

D. FAST PACKET MULTIPLEXING

Fast packet multiplexing (FPM) is a generic term for remote networking techniques that satisfy the following criteria [Ref. 2:p. 54]:

- the ability to transport a dynamically varying combination of voice, fax, video, synchronous data, asynchronous data, and LAN (local area network) traffic;
- high network efficiency, typically 90% or better;
- low network delay;
- predictable delivery of time-sensitive information.

Fast packet multiplexing is the most recent of four main multiplexing techniques designed for use in telecommunications networks. It is very similar to statistical packet multiplexing. As with previous multiplexing techniques, it is a way to reduce bandwidth needs by sharing bandwidth among network users, thereby reducing costs.

Unlike the other multiplexing techniques, it is designed to efficiently transmit a wide variety of time-sensitive information along the same network.

FPM has the following characteristics [Ref. 2:pp. 56-59]:

- it gathers each incoming channel's data into equal size cells (packets) for delivery over the network;
- it begins to forward cells of a message before all cells are completely received; i.e. cells pass through the FPM device rather than into and then out of the device;
- it can interrupt the delivery of one channel's message in favor of delivering a more time-sensitive (i.e. higher priority) channel's message (using cell boundaries to determine where interruptions may occur);
- the time it takes to transmit a cell is directly related to both the cell size and the bit rate of the network (outgoing) link; low rates and large cell size increase transmission time. The cell size is fixed by making it

proportional to the bit rate of the network link. Since cell sizes and bit rates of the links are fixed, service times for each cell are equal;

- it eliminates idle bandwidth from the incoming channels and transmits only active information, so more calls can be in progress than the number of physical channels available.

III. LITERATURE REVIEW

A. QUEUEING THEORY

1. The Erlang B (Loss) Formula

Voice communication systems using time-division multiplexing are often modeled stochastically as queueing models, using the Erlang loss system [Ref. 5:pp. 79-81]. Here, it is assumed that calls are initiated according to a Poisson process with rate λ, service times are exponentially distributed with mean length μ^{-1}, independent of each other and the arrival process; and if all servers (channels) are busy when a customer (caller) arrives, that customer cannot enter the system (gets a busy signal); that is, blocked customers are cleared (BCC). The ratio λ/μ is the offered load a, expressed in Erlangs. For a given number of channels c, the limiting probability of j busy channels is given by the truncated Poisson distribution:

$$\lim_{t \to \infty} P_j(t) = P_j = \frac{\dfrac{(\lambda/\mu)^j}{j!}}{\displaystyle\sum_{k=0}^{c} \frac{(\lambda/\mu)^k}{k!}} \quad (j = 0,1,\ldots c) \tag{1}$$

This formulation is also found in Ross [Ref. 6:p. 390].

The proportion of time that all c channels are busy is calculated by the Erlang B formula (or Erlang loss formula)

$$B(c,a) = \frac{a^c/c!}{\sum_{k=0}^{c} a^k/k!}, \tag{2}$$

where $a = \lambda/\mu$.

This formula is used to determine the number of channels c needed to achieve a particular blocking probability $B(c,a)$, given the offered load a in Erlangs. By plotting the Erlang loss formula B(c,a) against increasing values of a, curves for fixed values of c are obtained [Ref. 5:pp. 316-317]. Tables of these values have also been created. The carried load a' is also easily calculated:

$$a' = a\,[1 - B(c,a)]. \tag{3}$$

This is part of the method currently in use at DCA to determine the number of channels required along any particular trunk in the network modeling process for a given load.

B. MULTIPLEXER MODELS

Numerous models for various types of multiplexer have been developed. Similar models are used to analyze both computer and communication networks. A data-handling computer network is modeled by Anick, Mitra, and Sondhi [Ref. 7:pp. 1871-1894] using differential equations to describe the equilibrium buffer distribution. The model is used to determine the appropriate buffer size for a particular number of sources and grade of service. It is also used to determine the maximum number of sources to be allowed in the system. Integrated voice-data multiplexers are modeled in references [Ref. 8:pp. 8-14, Ref. 9:pp. 1124-1132, Ref. 10:pp. 833-846, and Ref. 11:pp. 1003-1009]. The first reference [Ref. 8:pp. 8-14] uses a continous-time queueing model which models performance of a flow control scheme for a movable boundary voice-data multiplexer and develops a decision rule based on data queue length to cutoff the priority of voice. Reference [Ref. 9:pp. 1124-1132] compares

two different voice-data multiplexer schemes, both of which use the movable boundary frame allocation scheme. The second scheme uses speech activity detectors (SAD's) so that the multiplexer also performs digital speech interpolation. This allows utilization of talker silences for transmission of additional voice and/or data. Performance measures include: probability of loss for voice calls, probability of speech clipping, speech packet rejection ratio, and expected message delay. The third reference [Ref. 10:pp. 833-846] uses the index of dispersion for intervals (IDI) as a measurement tool to characterize the complex arrival process resulting from superposition of separate voice streams. The paper also describes delays experienced by voice and data packets using a two-parameter approximation. The fourth reference [Ref. 11:pp. 1003-1009] models wideband packet technology integrating packetized voice and data using statistical multiplexing. It incorporates a flexible bandwidth allocation scheme with bit dropping; results using simulation show good voice quality, low delay and packet loss, efficient use of transmission bandwidth, and protection in overload. References [Ref. 12:pp. 847-855, Ref. 13:pp. 41-56, Ref. 14:pp. 703-712, and Ref. 15:pp. 718-728] all model packet voice multiplexers. Reference [Ref. 12:pp. 847-855] describes three models; a semi-Markov process, a continuous-time Markov chain, and a uniform arrival and service model; then compares numerical results of the queueing behavior of the three models to each other and to a discrete-event simulation and an M/D/1 analysis. All models assume multiple independent voice sources which form a queue for first-in-first-out (FIFO) service along a finite-capacity communications link. The second reference [Ref. 13:pp. 41-56] develops methodologies for evaluating the performance of variable bit rate voice

under the following two conditions: (1) at a fixed load when instantaneous fluctuations occur due to talker activity/inactivity and (2) under variable load when variations occur due to call on/off. The authors use a Markov chain model in conjunction with a software package to emulate packetized voice and describe the probabilistic bit-dropping pattern under various loading and traffic conditions. The third reference [Ref. 14:pp. 703-712] uses simulation and analytic modeling (M/D/1/K) to examine performance of a packet voice multiplexer queue which employs bit dropping during periods of congestion. Results indicate that significant capacity and performance advantages are gained in the multiplexer as a result of dropping the least significant bits when the system is congested. The fourth reference [Ref. 15:pp. 718-728] also uses an M/D/1/K queueing model for measuring performance of a voice packet network which uses bit dropping.

For purposes of this paper we have chosen a model which allows no queue to develop (blocked customers are cleared). Rather, we focus on the proportion of time that blocking occurs. That is, we assume that voice calls are so time-sensitive that no waiting time can be tolerated, so they are dropped (denied transmission) to avoid congestion. This is not a completely accurate description of what occurs in the multiplexer, however, we hope that it provides an adequate, albeit conservative approach.

IV. MODEL DEVELOPMENT

A. THE ERLANG MODEL

The first step toward developing the multiplexer model is to enhance the Erlang model with the addition of talkspurts. This will be used as a basis for the multiplexer model and also as a comparison model by which to measure the relative performance increase once a multiplexer is added.

1. Variables

In what follows, the following variables were used:

C(t) is used to represent the number of calls in progress at time t.

A(t) is used to represent the number of talkspurts (active calls) at time t.

K is the maximum number of calls allowed (= the number of channels).

Lambda (λ) is the call initiation rate (in call initiations per second).

Mu (μ) is the call termination rate (in call terminations per second).

μ^{-1} is the mean time (in seconds) that a call is in progress.

Alpha (α) is the talkspurt initiation rate (in initiations per second).

Beta (β) is the talkspurt termination rate (in terminations per second).

α^{-1} is the mean length of a silent period (in seconds).

β^{-1} is the mean time (in seconds) of talkspurt duration.

$\alpha/(\alpha + \beta)$ is the proportion of time that a call in progress of infinite duration is active.

$\beta/(\alpha + \beta)$ is the proportion of time that a call in progress of infinite duration is silent.

2. Model Assumptions

It is assumed that calls are initiated in accordance with a Poisson process with mean rate λ. The length of a call in progress is exponential with mean μ^{-1}. Blocked calls (customers) are cleared; that is, new calls are prevented from initiation if all available channels are in use. Let $\{C(t); t \geq 0\}$ be the number of calls in progress at time t.

Calls in progress alternate between active and inactive states as talkspurts are initiated and terminated. We model this process as an alternating renewal process where the length of the talkspurt is exponential with mean β^{-1} and the length of a silent period is exponential with mean α^{-1}. Let $\{A(t); t \geq 0\}$ be the number of calls in progress that are active at time t. Note that $A(t) \leq C(t)$.

It is also assumed that when a new call is initiated, it is immediately active; that is, a talkspurt is simultaneously initiated. When a call terminates, it may do so from either an active or inactive state.

3. Description

The model is a two-dimensional birth-and-death queueing model. It maintains the Markov property inherent in one-dimensional birth-and-death queueing systems, i.e the system occupies "states," and the rates at which changes of state occur depend only on the instantaneous state of the system and not on the past history of the process. However, two variables are required to define the state space. The bivariate process $\{(C(t), A(t)); t \geq 0\}$ is a continuous time Markov chain with the following:

$$
\begin{aligned}
&P\{C(t+h)=c,\ A(t+h)=a \mid C(t)=k,\ A(t)=j\} && \\
&\quad = [\lambda h + o(h)]\ I(j \le k)\ I(k < K) && \text{if} \quad c=k+1,\ a=j+1, \\
&\quad = [(k-j)\alpha h + o(h)]\ I(j < k) && \text{if} \quad c=k,\ a=j+1, \\
&\quad = [j\beta h + o(h)]\ I(j \le k)\ I(j > 0) && \text{if} \quad c=k,\ a=j-1, \\
&\quad = [\mu j h + o(h)]\ I(k > 0)\ I(j > 0)\ I(j \le k) && \text{if} \quad c=k-1,\ a=j-1, \\
&\quad = [\mu(k-j)h + o(h)]\ I(j > 0)\ I(j \le k) && \text{if} \quad c=k,\ a=j-1, \\
&\quad = 0 && \text{otherwise},
\end{aligned}
$$

$$
\textit{where } I(x<y)=\begin{cases} 1 \text{ if } x<y \\ 0 \text{ if } x \ge y \end{cases}.
$$

A rate diagram for this model, where the maximum number of available channels is three, is shown below in Figure 1; see [Ref. 6:p. 360] for discussion of transition rate diagrams.

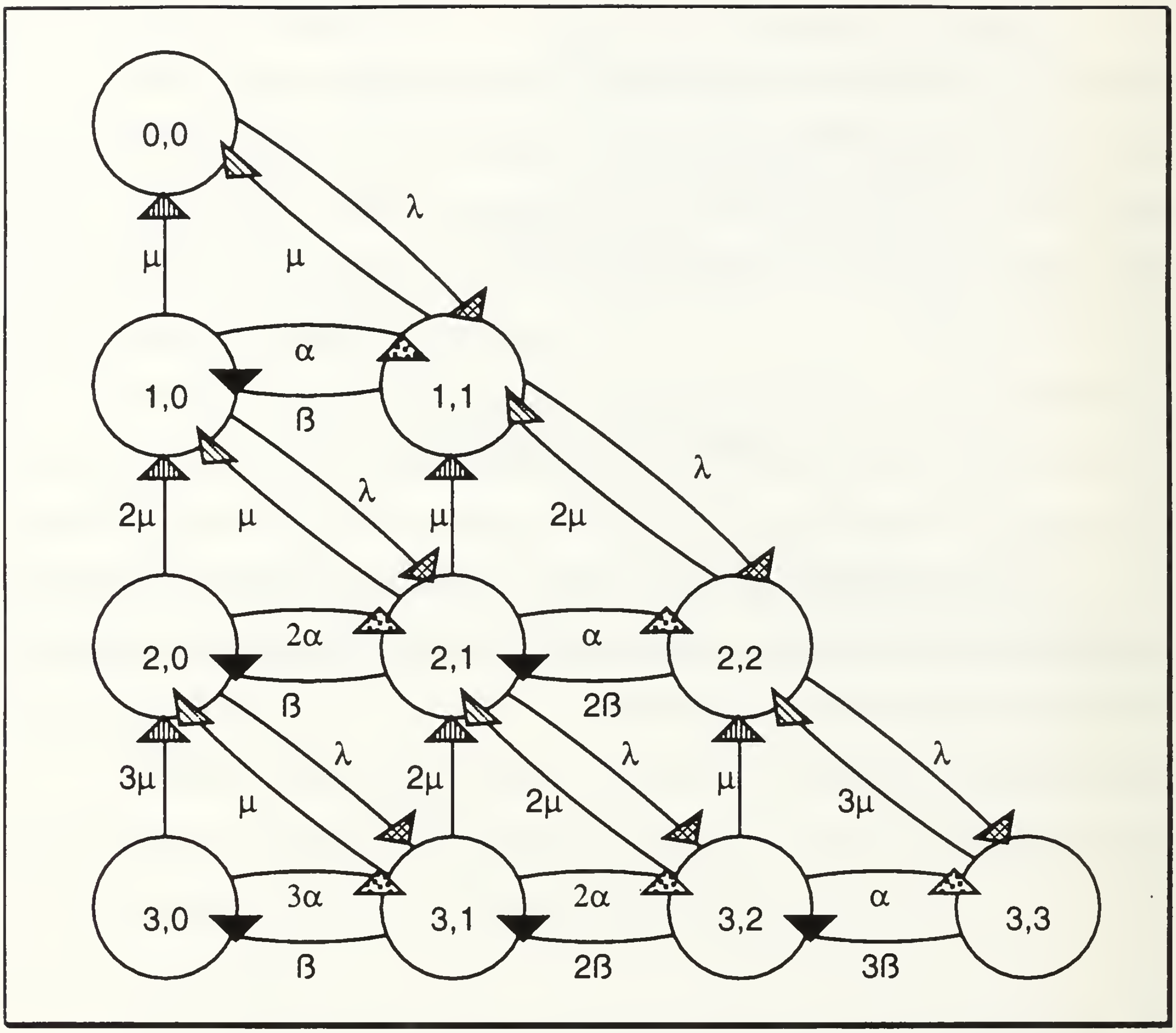

Figure 1. Graphical Representation of Three-Channel Bivariate Erlang System

Conservation-of-flow ("rate out = rate in") equations may be used to describe the system in equilibrium [Ref. 5:pp. 3-4]. We let the $\lim_{t\to\infty} P\{C(t) = k, A(t) = j\} = \Pi\{k,j\}$, where (k=0,1,..., K) and (j=0,1,...,k) represent the limiting distribution. The conservation-of-flow equations, which equate the rate the system leaves each state to the rate at which it enters that state, are shown below for a system with three available channels:

$$\lambda\Pi\{0,0\} = \mu\Pi\{1,0\} + \mu\Pi\{1,1\},$$

$$(\alpha + \lambda + \mu)\Pi\{1,0\} = \beta\Pi\{1,1\} + 2\mu\Pi\{2,0\} + \mu\Pi\{2,1\},$$

$$(\beta + \lambda + \mu)\Pi\{1,1\} = \lambda\Pi\{0,0\} + \alpha\Pi\{1,0\} + \mu\Pi\{2,1\} + 2\mu\Pi\{2,2\},$$

$$(2\alpha + \lambda + 2\mu)\Pi\{2,0\} = \beta\Pi\{2,1\} + 3\mu\Pi\{3,0\} + \mu\Pi\{3,1\},$$

$$(\alpha + \beta + \lambda + 2\mu)\Pi\{2,1\} = \lambda\Pi\{1,0\} + 2\alpha\Pi\{2,0\} + 2\beta\Pi\{2,2\} + 2\mu\Pi\{3,1\} + 2\mu\Pi\{3,2\},$$

$$(2\beta + \lambda + 2\mu)\Pi\{2,2\} = \lambda\Pi\{1,1\} + \alpha\Pi\{2,1\} + \mu\Pi\{3,2\} + 3\mu\Pi\{3,3\},$$

$$(3\alpha + 3\mu)\Pi\{3,0\} = \beta\Pi\{3,1\},$$

$$(2\alpha + \beta + 3\mu)\Pi\{3,1\} = \lambda\Pi\{2,0\} + 3\alpha\Pi\{3,0\} + 2\beta\Pi\{3,2\},$$

$$(\alpha + 2\beta + 3\mu)\Pi\{3,2\} = \lambda\Pi\{2,1\} + 2\alpha\Pi\{3,1\} + 3\beta\Pi\{3,3\},$$

$$(3\beta + 3\mu)\Pi\{3,3\} = \lambda\Pi\{2,2\} + \alpha\Pi\{3,2\}.$$

The sum of the terms on the left-hand side (rates out) is equal to the sum of the terms on the right-hand side (rates in). Any one of these equations is, thus, redundant and may be ignored. The remaining equations, along with the normalization equation

$$\sum_{k=0}^{3}\sum_{j=0}^{k}\Pi\{k,j\} = 1,$$

uniquely determine the limiting probabilities.

4. Parameter Values

If the average length of a phone call (μ^{-1}) is taken to be 180 seconds (three minutes), then $\mu = 1 \div 180$. The length of a talkspurt (β^{-1}) must be shorter than the length of a phone call for the model to be reasonable. We also want to maintain the proper proportion between the length of talkspurts and silent periods. Speech activity ranges from 28% to 42% depending on

cultural and language characteristics of the user population [Ref. 16:p. 1]. If voice conversations are assumed silent 60% of the time, then we need to have $\beta \div (\alpha+\beta) = 0.60$. The input value for λ is treated as variable; increasing the value of λ corresponds to an increasing load on the system, where load is defined to be $\lambda \div \mu$. Increasing the load increases the blocking probability. The maximum number of channels is also treated as variable. Increasing the number of channels decreases the blocking probability.

B. THE MULTIPLEXER MODEL

The multiplexer model begins with the Erlang model as described above, then adds the three main features which are characteristic of how a multiplexer functions. The first and most important distinguishing characteristic of the multiplexer is that it allows more calls in progress than the actual physical number of channels. This is accomplished by taking advantage of the silent periods in each conversation to merge together packetized talkspurts from multiple conversations. Secondly, it compresses the packetized talkspurt to a fraction of its original length. Third, and lastly, it appends header information to each packet, to allow the talkspurt to be recreated at the destination node. See [Ref. 17:p. 430] for additional discussion of the information contained in the packet header.

1. Variables

The following are additional variables that appear in the multiplexer model. A new variable (J) is added, and the value of K is redefined. Also, β^{-1} is replaced by $(\beta^{-1})^*$, and service rate (s) is added.

J is the maximum number of talkspurts allowed (equal to the number of physical channels).

K is the maximum number of calls allowed to be in progress (may be several times greater than J).

$(\beta^{-1})^*$ is the new mean talkspurt length in units of bits per talkspurt after compression and addition of packet headers.

b is the number of bits per second produced by the coding scheme.

s, the service rate in bits per second, is simply the outgoing channel rate (of the wideband channel).

β^*s is the new departure or service rate of talkspurts (in talkspurts per second), where β^* is the inverse of $(\beta^{-1})^*$.

2. Additional Model Assumptions for the Multiplexer Model

Although more calls than channels are allowed, new calls are blocked when the number of active calls in progress (talkspurts) equals the number of available channels. Voice packets belonging to a call in progress are also blocked (lost or "clipped") when the number of active calls in progress equals the number of available channels.

3. Description

In the multiplexer, all talkspurts from all incoming channels flow through a buffer, where they are "packetized" and sent forward along a single wideband channel. The multiplexer divides talkspurts into fixed size packets and attaches certain header information that allows the talkspurt to be reconstructed at the destination node by a demultiplexer. The multiplexer can also compress the packetized information so that it uses fewer bits, thus occupying less space as it moves through the channel. Typical compression schemes use either a 2-to-1 or 4-to-1 rate of compression.

The intelligent multiplexer model is also a bivariate process $\{(C(t), A(t)); t \geq 0\}$ and a continuous-time Markov chain with the following:

$$
\begin{aligned}
&P\{C(t+h)=c,\ A(t+h)=a \mid C(t)=k,\ A(t)=j\} \\
&\quad = [\lambda h + o(h)]\, I(j < J)\, I(k < K) && \text{if} \quad c=k+1,\ a=j+1, \\
&\quad = [(k-j)\alpha h + o(h)]\, I(j < J)\, I(j < k \le K) && \text{if} \quad c=k,\ a=j+1, \\
&\quad = [j(\beta^* s)h + o(h)]\, I(0 < j < J)\, I(k \le K)\, I(j \le k) && \text{if} \quad c=k,\ a=j-1, \\
&\quad = [\mu j h + o(h)]\, I(k > 0)\, I(0 < j \le k \le K)\, I(j < J) && \text{if} \quad c=k-1,\ a=j-1, \\
&\quad = [\mu(k-j)h + o(h)]\, I(0 < j < J)\, I(j < k < K) && \text{if} \quad c=k,\ a=j-1, \\
&\quad = 0 && \text{otherwise,}
\end{aligned}
$$

$$
where\ I(x<y)=\begin{cases} 1 \text{ if } x < y \\ 0 \text{ if } x \ge y \end{cases}.
$$

A rate diagram for the multiplexer model, where the maximum number of available channels is three, is shown below in Figure 2; see [Ref. 6:p. 360] for discussion of transition rate diagrams.

In the multiplexer model, there can be two types of blocking. Outside calls can be blocked from initiation (external blocking) and calls in progress can be blocked from transmitting a talkspurt (internal blocking). Both kinds of blocking occur when the number of talkspurts (active calls) is at the line capacity

$$
\lim_{t\to\infty} P\{A(t)=J\} = \sum_{k=J}^{K} \lim_{t\to\infty} P\{C(t)=k, A(t)=J\}.
$$

The blocking of calls from initiation also occurs when the number of calls in progress is at the maximum allowed (C(t)=K). The proportion of time this occurs is given by

$$
\lim_{t\to\infty} P\{C(t)=K\} = \sum_{j=0}^{J} \lim_{t\to\infty} P\{C(t)=K, A(t)=j\}.
$$

In comparison, blocking in the Erlang model occurs only when the number of calls in progress equals the number of physical channels. There is

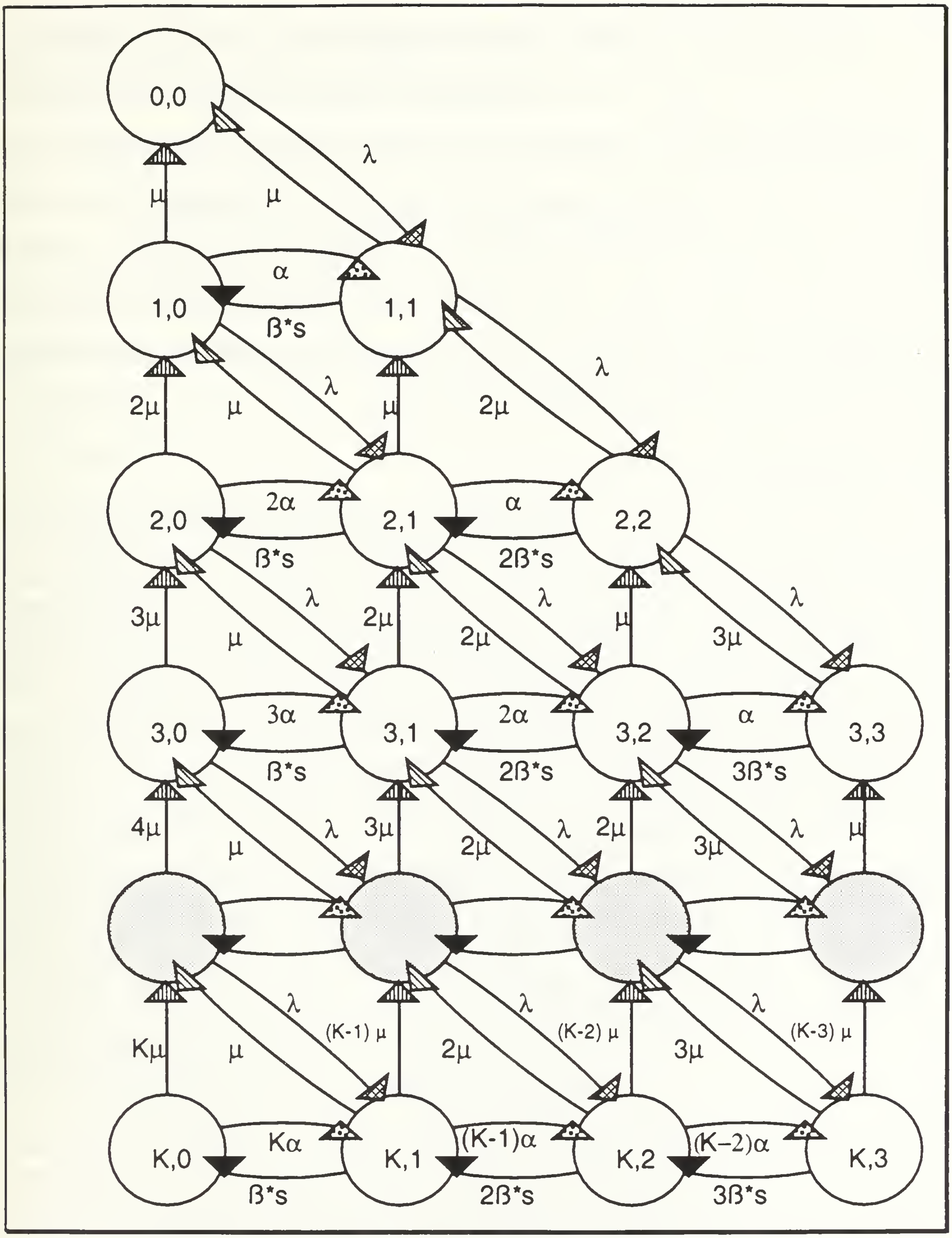

Figure 2. Graphical Representation of Three-Channel Smart Mux Model

no internal blocking. Note that under reasonable loading it is possible for $A(t) \leq J \leq C(t) \leq K$, where J is the maximum number of active calls that the transmission line can support and K is the maximum number of calls allowed in the system. For purposes of this paper, we will refer to the external blocking that occurs when $C(t)=K$ as outer blocking. The internal and external blocking that occurs when $A(t)=J$ will be called inner blocking. By adding the two together and subtracting out the joint limiting probability that $\{C(t)=K, A(t)=J\}$, we get the total probability of blocking.

D. PARAMETER VALUES

The value for length of talkspurts (β^{-1}) in the Erlang model changes in the multiplexer case to account for both compression of the packetized talkspurt and for header information appended to each packet. Packet lengths are expressed in terms of bits rather than time, but can be converted to units of time if given the line rate of the transmission medium in terms of bits per second (bps). The voice packet size depends on the coding scheme used. For 32 Kbps, ADPCM coding, and a packetization period of T=16 milliseconds (ms), the packet size is 512 bits or 64 bytes (there are 8 bits per byte), plus a header [Ref. 16:p. 1]. A talkspurt of 352 ms is divided into $352 \div 16 = 22$ packets and contains a total of 11264 bits (1408 bytes). Each packet is then compressed. A compression factor of four reduces each packet to 128 bits. Appending a packet header of 10 bytes to each compressed packet increases the length to 208 bits (26 bytes). Thus the number of bits in a talkspurt of 352 ms is 4576 after compression and addition of headers. This compression and addition of packet headers to alter the original mean talkspurt length, β^{-1} (in units of

seconds), results in the new mean talkspurt length in units of bits, $(\beta^{-1})^*$, defined in the multiplexer model as follows:

$$(\beta^{-1})^* = \beta^{-1} \times T^{-1} \times (\text{\# bits/packet}) \times ((1+ \text{compress}) + \text{header proportion})$$

$$= \beta^{-1} \times b \times ((1+ \text{compress}) + \text{header proportion})$$

$$= \text{number of bits per average talkspurt},$$

where b, the number of bits per second produced by the coding scheme, is equivalent to the number of bits per packet (e.g. 512) divided by the packetization period T (e.g. 16 ms per packet). Also note that $\beta^{-1} \times T^{-1}$ is equal to the mean number of packets in a talkspurt.

Compress is set equal to four (4) to indicate a 4-to-1 compression of data by the multiplexer. Packet header information is assumed to be 10 bytes (attached to a 64 byte packet), [Ref. 16], for a header proportion of $10 \div 64 = .15625$.

In addition, the service rate of the outgoing channel is now many times larger than any of the incoming channels. The Defense Communications Agency commonly uses T1 lines, which carry 1.544 Mbps (1.536 Mbps after accounting for the signalling channel). The T1 lines may be divided into 1.536 Mbps÷32 Kbps = 48 separate channels. Therefore the outgoing T1 rate is 48 times larger than the rate of the encoding scheme. A talkspurt of 352 ms (without compression and addition of packet header) will take 11264 bits÷1.536 Mbps = 0.073 ms to transmit on a T1 line.

In this multiplexer model, however, we do not necessarily want to assume full T1 rates for the outgoing channel. Rather, we need to be able to look at fractional T1 rates for lighter traffic loads, so we assume that the outgoing rate is equal to 32 Kbps multiplied by the maximum number of

active calls allowed (labeled J in the multiplexer model described above; labeled A in the computer code). The incoming channel rate is set equal to b = 32 Kbps. The ratio of the outgoing channel rate to the rate of an active incoming channel is set equal to J. In the multiplexer model, $J \times b$ is defined as the service rate, s. The termination rate for talkspurts in the multiplexer model is given by $\beta^{*}s$.

V. APPROXIMATIONS

A. THE ERLANG MODEL APPROXIMATION

As noted earlier, the truncated Poisson formula is used to calculate the limiting probabilities for an Erlang loss system with maximum K channels and input parameters λ and μ; that is, a model for the calls in progress $\{C(t); t \geq 0\}$ is a continuous time Markov chain with transition rate diagram shown in Figure 3 [Ref. 6:p. 360].

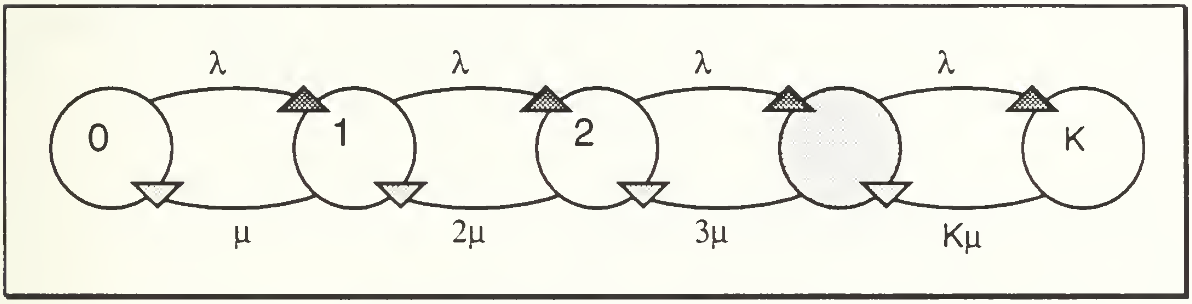

Figure 3. Transition Rate Diagram for Calls in Progress

To deal with the bivariate Erlang system, we need to consider the two additional parameters (α and β) which describe talkspurt initiation and termination. Fix the number of calls in progress equal to $k \leq K$. A model for the number of active calls in progress is a continuous time Markov chain with the rate diagram shown in Figure 4. Since the calls in progress are independent of each other, the limiting distribution of having j active calls is described by the binomial distribution;

$$\lim_{t \to \infty} P\{A(t) = j | k \text{ calls in progress}\} = \binom{k}{j}\left(\frac{\alpha}{\alpha+\beta}\right)^{j}\left(\frac{\beta}{\alpha+\beta}\right)^{k-j}. \tag{4}$$

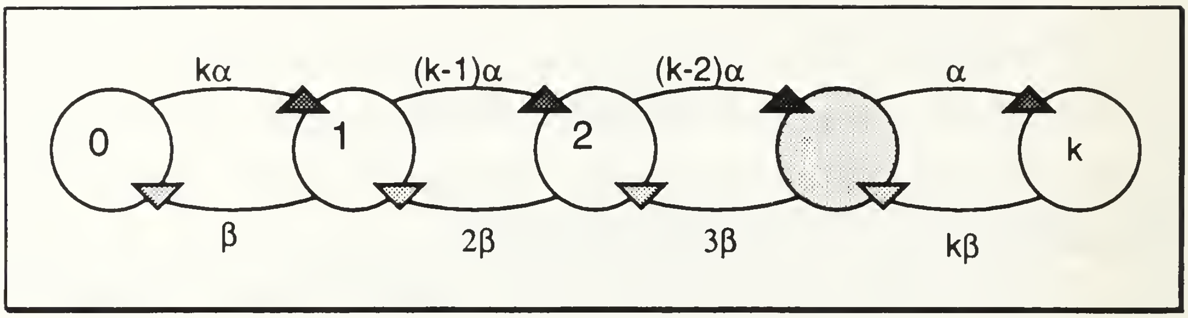

Figure 4. Transition Rate Diagram for Active Calls in Progress

Limiting probabilities for the bivariate Erlang system can be approximated by combining the truncated Poisson distribution (1) with the binomial;

$$\lim_{t\to\infty} P\{A(t)=j, C(t)=k\} = \frac{\frac{(\lambda/\mu)^k}{k!}}{\sum_{i=0}^{K}\frac{(\lambda/\mu)^i}{i!}} \binom{k}{j}\left(\frac{\alpha}{\alpha+\beta}\right)^j \left(\frac{\beta}{\alpha+\beta}\right)^{k-j}, \tag{5}$$

where (k = 0,1,...., K) and (j= 0,1,...., k).

B. THE MULTIPLEXER MODEL APPROXIMATION

For the multiplexer model, the binomial probability of having j talkspurts, given k calls in progress, must be adjusted to reflect the new restriction that the number of talkspurts cannot exceed the number of physical channels J, and that J may be less than k. The following form of the truncated binomial [Ref. 5:p. 109] was used rather than the binomial distribution used in the Erlang model.

$$P_j(k) = \lim_{t\to\infty} P\{A(t)=j \mid k \text{ calls always in progress}\} = \binom{k}{j}\left(\frac{\alpha}{\beta * s}\right)^j P_0(k), \tag{6}$$

$$\text{where } P_0(k) = \left[\sum_{j=0}^{J}\binom{k}{j}\left(\frac{\alpha}{\beta * s}\right)^j\right]^{-1}$$

for j ≤ k, where (k = 0, 1,...., K) and (j= 0, 1,...., J).

The truncated Poisson distribution (1) is still used to find the probability of k calls in progress (k=0,1...,K), but now it yields an approximate rather than an actual limiting probability, since it fails to account for the additional internal blocking in the multiplexer model. Thus, the truncated Poisson yields a conservative estimate of the external blocking that occurs when the maximum allowed number of calls are in progress (outer blocking).

The joint approximate limiting probabilities for the multiplexer model are similarly found by multiplying the truncated Poisson by the truncated binomial; that is,

$$\lim_{t\to\infty} P\{C(t)=k, A(t)=j\} = \left[\frac{\frac{(\lambda/\mu)^k}{k!}}{\sum_{k=0}^{K}\frac{(\lambda/\mu)^k}{k!}}\right]\left[\frac{\binom{k}{j}\left(\frac{\alpha}{\beta * s}\right)^j}{\sum_{j=0}^{J}\binom{k}{j}\left(\frac{\alpha}{\beta * s}\right)^j}\right], \tag{7}$$

for j ≤ k, where (k = 0,1,...,K) and (j = 0,1,...,J).

VI. SOLUTION TECHNIQUES

A. SOLVING SETS OF LINEAR EQUATIONS

Two programs were written to solve the system of linear equations determining the limiting distribution (for both the Erlang and the multiplexer models). One uses GAMS [Ref. 18], which is a software package developed to solve large mathematical (linear and non-linear) programming models. The other uses APL to solve the system of equations through matrix inversion and was developed by Professor Patricia Jacobs of the Naval Postgraduate School. The GAMS programs may be found in Appendix A (Erlang model) and Appendix B (multiplexer model). The APL program for the multiplexer model, in Appendix C, may also be used to solve the Erlangian system with some adjustments to the input variables.

This solution technique, though accurate, was found to be useful only for small problems. Using an IBM mainframe computer, the GAMS programs were solvable for systems of about 15 channels in the Erlang model (with a load of 15 Erlangs). Beyond that, the solver encounters overflow problems. For discussion of the computational instability of solving the matrix equations and alternative solution techniques, see Anick, Mitra, and Sondhi [Ref. 7:pp. 1873-1874]. The APL programs MATRIXE and MATRIXM were solved using APL2 on an IBM mainframe. Without increasing the workspace size beyond the default, it is possible to solve for systems of up to size 21×21; that is, where 21 is the number of both the maximum number of calls in progress and the maximum number of active calls in progress allowed (253

states). It is possible to increase the size of the workspace from the default of 65% to a maximum of 85%, and thereby increase the size of the matrix which can be solved. However, it takes a long time to solve the larger systems, especially when creating tables of multiple runs.

B. APPROXIMATION

The approximation routine APPROX, written in APL, calculates the limiting probabilities for both the Erlang and the multiplexer models. It may be found in Appendix D. The approximation routine is much faster than solving the sets of linear equations required to find the limiting distribution of the bivariate models. It is also able to solve larger problems, given the same APL workspace size. On the IBM mainframe APPROX can solve problems up to size 32 × 32 (561 states) before encountering underflow errors in the results (due to extremely small limiting probabilities, on the order of 1E¯75 or smaller). The approximation will solve for systems of up to C = 175 (maximum calls in progress allowed) without halting due to domain errors (numbers larger than 1E75 in the intermediate calculations). Results from these larger systems may, however, be inaccurate due to the underflow errors mentioned above, depending on the value of A (number of physical channels). For instance, when solving for a system with C equal to 40, the approximation was able to calculate the results for as many as A = 33 channels before encountering underflow errors.

C. VALIDATION OF THE COMPUTER CODE

1. Validating Code for the Erlang Model

The computer code was validated in two ways. First the results for one, two and three-channel systems were calculated by hand for a particular set of values for λ, μ, α and β to ensure that results matched those of the computer programs. Second, numerous cases were calculated using both the APL (MATRIXE) and the GAMS (ERLANG) programs to ensure that the two different programs yield the same results. The APL (APPROX) program for the Erlang model was then compared with results from APL (MATRIXE) to ensure that the approximation routine yields results which are close to the actual limiting probabilities.

2. Validating Code for the Multiplexer Model

The multiplexer codes (MUX in GAMS and MATRIXM in APL) were first validated by ensuring they yield the same results as the Erlang codes (ERLANG in GAMS and MATRIXE in APL) when all the same parameter values are used as inputs (i.e. no change in the service rate, no compression or packet header, and the number of channels J equals the maximum number of calls allowed K). The APL (MATRIXM) and GAMS (MUX) programs were also compared to each other to ensure the same results for various sets of input parameters. Results were also checked for internal consistency; that is, individual input parameter values were changed separately to check that the output values change as expected. Finally, the results of the APL (APPROX) program for the multiplexer model were compared with those of the APL (MATRIXM) program to check the validity of the approximation routine and determine the range of values over which the approximation yields results

close enough to be used as a tool in determining the reduction in bandwidth requirements.

VII. NUMERICAL RESULTS

A. ACTUAL VS. APPROXIMATED BLOCKING PROBABILITIES

Results of several comparisons between the actual (MATRIXM) and approximated (APPROX) multiplexer model are shown in Appendix E. Comparisons were made for systems allowing a maximum of C = 5, 10, 15, 20, and 30 callers, assuming speech activity (average proportion of time a call in progress is active) of 35%. Traffic loads displayed depend on the value for C; the larger the value for C, the heavier the loads, though not larger than the value for C itself. This restricts the results, and analysis of those results, to the range of values for blocking probabilities which might be considered reasonable to plan for when designing a telecommunications system.

The results shown in Appendix E indicate that the approximated outer blocking (OUTBLA) becomes very close to the actual value (OUTBL) as the gap between A (number of channels) and C (maximum number of calls allowed) decreases. In fact, when A equals C, OUTBL and OUTBLA are also equal. The approximated inner blocking (INBLA) also becomes closer in value to actual inner blocking (INBL) as A and C become closer. The probability of inner blocking decreases, becoming zero when A equals C. The size of the limiting probability of inner blocking is, therefore, also closely linked to the difference between the actual and approximated outer blocking probabilities. As inner blocking decreases, OUTBLA becomes closer to the actual values. Note that there is a trade-off between outer and inner blocking.

Inner blocking increases as the gap between A and C increases, while outer blocking decreases.

The question is, at what point are the approximations close enough to the actual values to be used to determine limiting probabilities; that is, how close does A need to be to C ? For inner blocking probabilities, the approximation results are extremely close to the actual values for even large relative gaps between A and C. For instance, when C = 5, 10, 15, 20, and 30, INBLA is accurate to 3 decimal places when A = 2, 3, 4, 4, and 5, respectively (for all traffic loads displayed). Also, when INBLA is accurate to 3 decimal places, the first 2 decimal places hold zeros. For the same values of C and the same traffic loads, OUTBLA is accurate to approximately 2 decimal places for A = 3, 3, 4, 4, and 5, respectively. Thus, INBLA is somewhat more accurate than OUTBLA and the size of the values for INBLA may be a good predictor of the accuracy of both INBLA and OUTBLA. Suppose we develop a 'thumb rule' that states: when INBLA is equal to zero in the first 'x' decimal places, (a) INBLA is accurate to within 'x+1' decimal places, and (b) OUTBLA is accurate to within 'x' decimal places. Close examination of the results in Appendix E indicate that our thumb rule is accurate for all values of C, A, and load shown, if the values for OUTBL are rounded to 'x' decimal places for comparison with OUTBLA. Thus, by using the approximated inner and outer blocking together, we can tell fairly accurately how close (within number of decimal places) OUTBLA is to the actual outer blocking probability by looking at the proportion of inner blocking.

As to answering the question posed, i.e. how close must A be to C for accurate results, the response depends on two things; (1) the level of accuracy

desired, and (2) the value of C. For telephone traffic engineering purposes, the level of accuracy necessary is generally 2 or 3 decimal places, so we want the values for INBLA to have zeros in at least the first 2 decimal places. Clearly, the ratio of A to C necessary for accurate results decreases as C gets larger.

Having developed a thumb rule methodology for determining the accuracy of the multiplexer approximation results without direct comparison with actual values, we may now look at the results of the approximation independently, allowing analysis of larger systems. The approximate results are much more quickly obtained, making it feasible to conduct multiple runs for different levels of speech activity. Analysis of these results, displayed in Appendix F, is the subject of the next section.

B. SENSITIVITY ANALYSIS OF THE APPROXIMATED INNER BLOCKING PROBABILITIES

The approximation routine for the multiplexer model was run for different values of the initial mean length of a talkspurt, β^{-1}, and mean length of a silence, α^{-1}, such that speech activity occupies 28 percent, 35 percent, and 42 percent of a call in progress. This was to determine sensitivity of the inner blocking probabilities (4) to changes in speech characteristics. Since the approximated outer blocking probability is calculated from the Erlang loss formula (2), it is not affected by any parameters other than λ, μ, and K.

The average length of a phone call, μ^{-1}, was taken to be 180 seconds (3 minutes) for all runs. Speech activity rates considered were 28, 35 and 42 percent. The mean talkspurt and silence lengths are assumed to be 288 ms and 740 ms for the first case, 352 ms and 650 ms for the second case, and 420 ms

and 580 ms for the third case, respectively. Values for the last two cases are the same as those used by Sriram and Lucantoni [Ref. 14:pp. 703-712].

Results of runs for C = 5, 10, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 125, 150, and 160 are given in Appendix F. To use the table in Appendix F, you first find the load (column 1) for which outer blocking probability (column 2) is less than or equal to a specified value, say 0.01. In the case of C = 20, the corresponding load is 12. The next three columns give the approximate inner blocking probability for speech activity rates of 28, 35, and 42 percent, respectively. The most conservative (highest) estimate of inner blocking would, of course, be found in the last column, representing the 42% activity level. If you wish a total blocking probability of no more than 0.01, accurate to within 2 decimal places, then you find the value of A for which, given a load of 12, the value for inner(42) is zero in at least the first 2 decimal places, and the addition of the outer and inner(42) blocking probabilities is closest to, but still no greater than, 0.01. Notice that we are not subtracting out the joint blocking probability (as on page 21) after adding together the inner and outer blocking probabilities. This is primarily because the joint blocking probabilities are so small as to be insignificant to the results of the calculations. Also, any error thus induced would be on the side of conservatism, and therefore tolerable. For this example, the value for A (number of channels) which meets the requirement is 5, which is one-fourth of the value for C (maximum number of callers).

Figure 5 shows a graphical representation of the data from Appendix F, for C = 20 callers and speech activity of 35%. It actually represents two graphs superimposed on each other. The one graph shows <u>outer</u> blocking probability

versus load when C (maximum number of callers allowed) is equal to 20. This is calculated using the Erlang loss formula (2). Curves for C<20 would be higher and to the left of the curve for C=20 (+ symbol); curves for C>20 would be lower and to the right. Graphs showing the curves for selected values of C ranging from 1 to 80 may be found in Cooper [Ref. 5, pp. 316-319]. Cooper uses different symbols and also uses a logarithmic scale for the blocking probabilities, which gives a different shape to the curves. The calculations and results, however, are the same. The other graph displayed in Figure 5 is <u>inner</u> blocking probability versus load for various values of A (A = 3, 4, 5, 6) when C=20 and speech activity is 35%. Remember that the value for A represents the number of channels (or equivalent bandwidth) available. The goal is to minimize the value of A while maintaining a specified standard of service; in this case, total probability of blocking no greater than .01.

From Appendix F we see that when C=20 and the load is 12 erlangs, the outer blocking probability equals .009796, and 12 is the highest load the system can take without exceeding the .01 limit on total blocking. Inner blocking can be no greater than .000204. We must find the value for A which satisfies this requirement. For speech activity of 35%, A=5 channels is sufficient, with inner blocking of .000148. Three channels is clearly too few, four channels will only work at the 28% level of speech activity, and six channels exceeds the standard of service required.

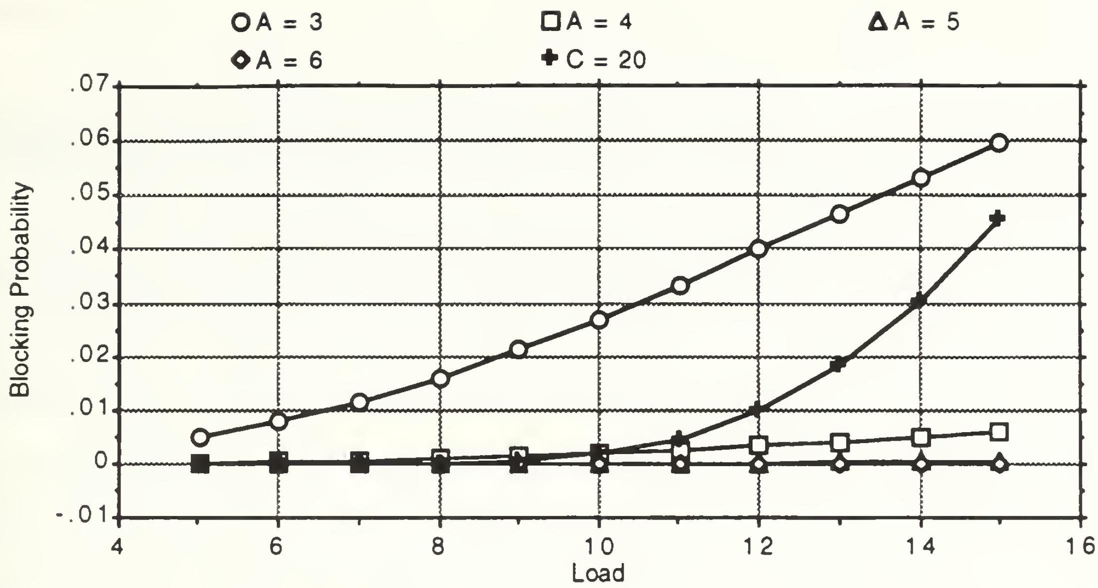

Figure 5. Outer Blocking Probability vs. Load for C = 20, shown with Inner Blocking Probability vs. Load for various values of A (given C = 20), assuming 35% speech activity. From Appendix F.

Given specific criteria for desired blocking probabilities and accuracy levels, we can make tables of the values for the load and for A necessary to meet those criteria for each value of C. Conversely, if the load is fixed, there is a specific value for C which will meet the desired blocking probability. We can also determine the magnitude of the effect that the proportion of speech activity has on the value of A chosen. Table 1 below is an example, where the desired total blocking probability (again ignoring joint blocking) is no greater than 0.01 and is accurate to within three decimal places. The data from Table 1 are graphically depicted in Figures 6 through 8.

TABLE 1. VALUES OF A FOR GIVEN LEVELS OF SPEECH ACTIVITY, WITH TOTAL BLOCKING NO GREATER THAN 0.010; ACCURATE TO 3 DECIMAL PLACES.

C	LOAD	A: INNER (28)	A. INNER (35)	A. INNER (42)
5	3	3	3	4
10	4	3	3	4
20	12	4	5	5
25	16	5	5	5
30	20	5	5	5
35	24	5	5	6
40	29	6	6	7
45	33	6	6	7
50	37	6	6	7
60	46	6	7	7
70	56	7	8	8
80	65	7	8	9
90	74	7	8	9
100	84	8	9	10
125	107	8	9	10
150	131	9	10	11
160	141	9	11	12

Results of this study indicate that for low loads, the addition of multiplexers provides very little, if any, advantage in terms of reducing the number of channels necessary to provide acceptable blocking probabilities. The advantage increases dramatically as load increases. This is shown in Figure 6, where C and A represent the number of channels needed without and with multiplexers, respectively. Also, the level of speech activity does

have some impact on the number of channels required. However, the values of A for 35% speech activity are within ±1 channel of the values obtained for the lower (28%) and upper (42%) speech activity levels. This is shown in Figure 7, which gives a closer view of the bottom three lines from Figure 6. Figure 8 shows the use of regression analysis to interpolate the number of channels required for loads between those listed. The quadratic equation generated by the regression gives a model for predicting the value of A (on the Y axis) when the load (on the X axis) is known, given desired total blocking of no greater than 0.01 (accurate to within 3 decimal places) and speech activity of 35%. Note that since the information in Figures 6 through 8 is taken from Table 1, all three figures assume total desired blocking probabilties of .01. Once this is fixed, it fixes the value of C for every corresponding load, and vice versa. Therefore, the values given for A are dependent on the value of C as well as on the load, and C could be substituted for load on the X axis of the three graphs. The fact that load and C are dependent on each other allows us to use just the load to determine the value of A (number of channels needed for a multiplexed system) without doing the intermediate calculation to find the value of C (number of channels required for a non-multiplexed system), given, of course, that we know the desired total blocking probability and level of accuracy required.

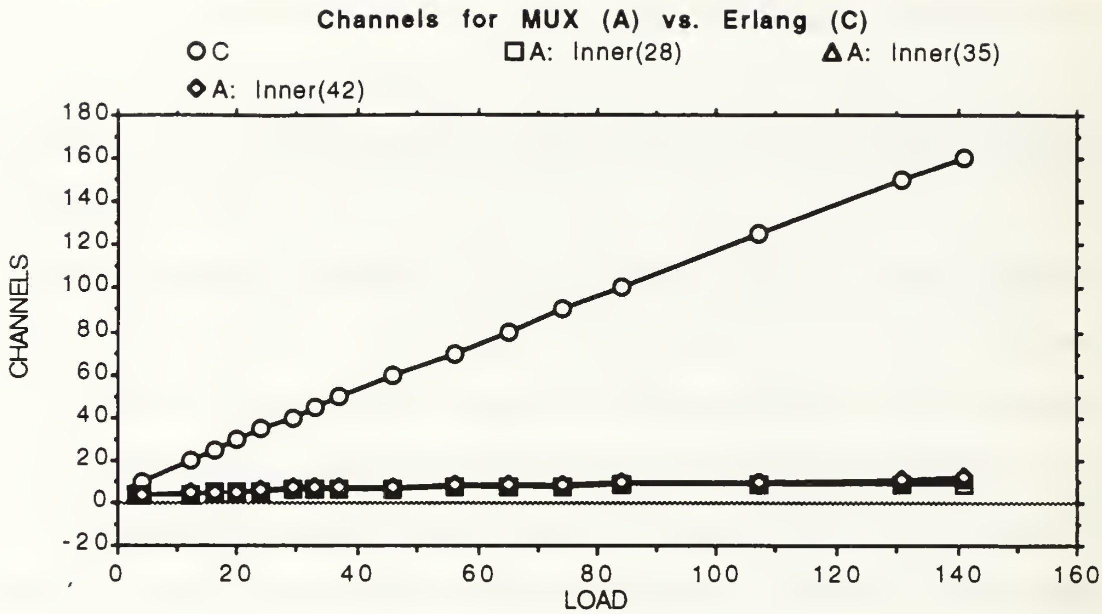

Figure 6. Channel Reduction in the Multiplexer Model

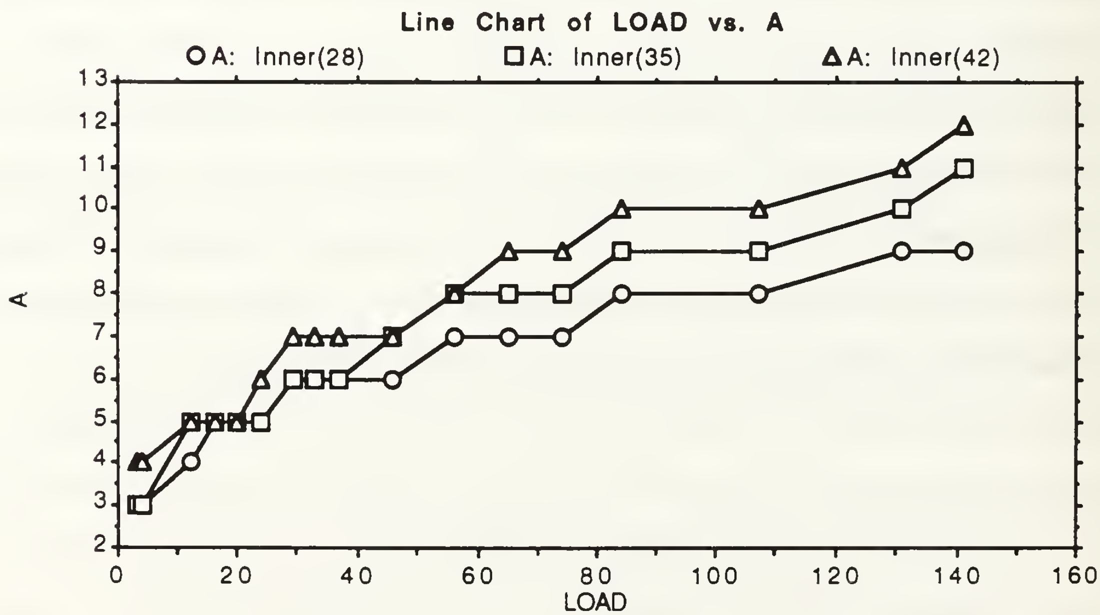

Figure 7. Channels Required for Various Speech Activity Levels; Mux Model

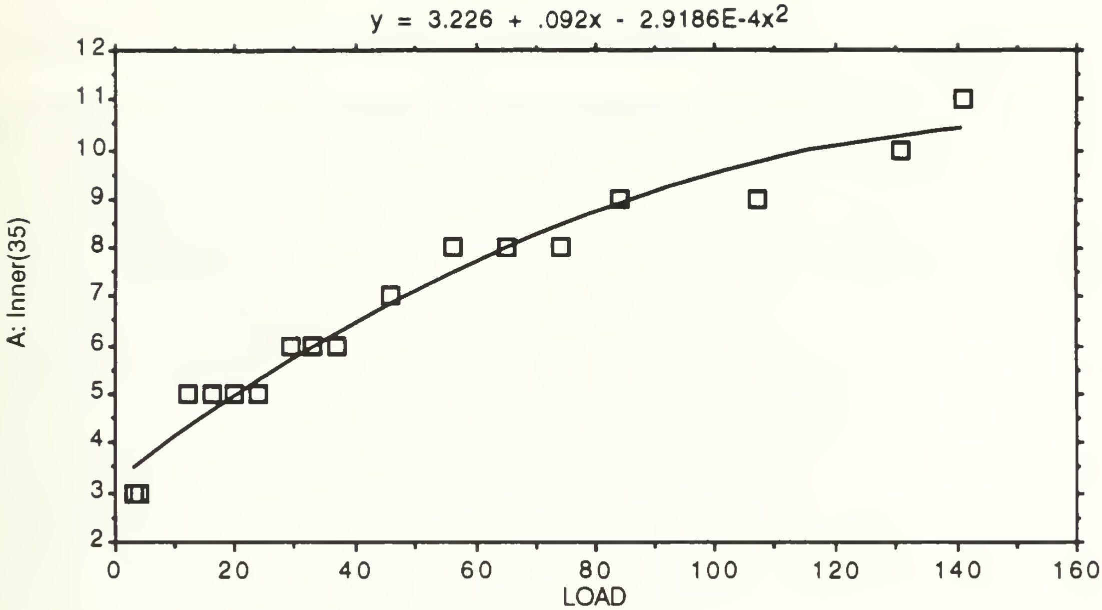

Figure 8. Regression on Channels (A) for Mux Model vs. Load (35% speech activity)

VIII. CONCLUSIONS

In this study, we first developed stochastic models of a single-node telecommunications system both without and with the addition of an intelligent multiplexer (the bivariate Erlang and the Multiplexer models, respectively). The models were solved using matrix equations to compute the joint limiting probabilities for k callers and j talkspurts, as well as outer blocking and inner blocking probabilities (respectively the proportion of time the maximum allowed numbers of callers and talkspurts are in the system). Both GAMS (Appendices A and B) and APL (Appendix C) were used to do the computations for the purpose of validating the computer code.

Approximation routines (Appendix D) were then developed that were capable of performing the calculations much faster and for larger systems. Results from the multiplexer approximation were compared with the actual blocking probabilities computed from the matrix equations (Appendix E). A rule of thumb based on the size of approximate inner blocking probabilities was devised to determine the accuracy of both the approximate inner and outer blocking probabilities. Sensitivity analysis was also done to determine the effect of different levels of speech activity on the inner blocking probabilities (Appendix F). Given desired outer blocking and total blocking probabilities, as well as desired level of accuracy, it is possible to determine the number of channels (A) required to handle a particular traffic load in the multiplexer model, and compare this with the number of channels (C) required in the Erlang model.

Analysis of the results from the tables in Appendix F indicate that addition of a multiplexer significantly reduces bandwidth requirements, particularly for heavy loading. The multiplexer advantage decreases to the point of insignificance as the load becomes very small (less than 3). The point at which the addition of multiplexers becomes advantageous depends on the cost of the adding multiplexers to a network vs. the cost of leasing the additional channels or bandwidth. These costs are affected by the number of nodes in a network, the geographical distances between nodes, and the loading along the links between nodes. A lightly loaded network with many nodes which are close together will benefit less than a heavily loaded system with long distances between relatively few nodes.

This study does not compare model results with data from actual systems. Nor was the multiplexer model developed to fit data from a real system. The Erlang loss formula has been found to have much practical use in designing voice telecommunications systems which do not utilize intelligent multiplexers. It is hoped that the methodology employed to adapt the bivariate Erlang model to reflect particular multiplexer characteristics will likewise prove useful in determining bandwidth requirements for systems which use intelligent multiplexers. Further study is recommended to validate the multiplexer model through comparison with data from a multiplexed voice system. Adjustments to the model may also be made to reflect different performance characteristics and input parameter values.

APPENDIX A

The following GAMS program computes limiting probabilities for the bivariate Erlang system. Results shown are for a three-channel system with the following characteristics:

Mean call length (μ^{-1}) of 3 minutes (180 seconds).

Load (λ/μ) equal to 1.

Mean talkspurt length (β^{-1}) of 352 ms (.352 seconds)

Mean length of silence (α^{-1}) of 650 ms.

Speech activity of 35% ($\alpha \div (\alpha+\beta) = 0.35$).

```
*------------GAMS AND DOLLAR CONTROL OPTIONS-----------------------
*                (SEE APPENDICE B & C)


OPTIONS
     LIMCOL =  0 , LIMROW  = 0    , SOLPRINT = OFF , DECIMALS = 6
     RESLIM =  200, ITERLIM = 20000, OPTCR = 0.1 , SEED = 3141;

*-------------DEFINITIONS AND DATA---------------------------------
  SET
     C   channels /0*3/;

  ALIAS (C,A);

  SCALARS
     alpha  talkspurt arrival rate in SEC(inverse) /1.53846/
     beta   talkspurt departure rate in SEC(inverse)  /2.8409/
     lambda  customer arrival rate in SEC(inverse) /.005556/
     mu      customer departure rate in SEC(inverse) /0.005556/
     totprob  /1/
     B       maximum number of channels /3/;

*--------------------MODEL-----------------------------------------
  POSITIVE VARIABLES
      P(C,A)    limiting probability that system is in that state
      ZP(C,A)   z-plus dummy variable
      ZM(C,A)   z-minus dummy variables;

  VARIABLE
      Z          objective function to be minimized;

  EQUATIONS
      OBJ             dummy variables
      PROB(C,A)       calculate limiting probabilities
      NULL(C,A)       delete infeasible state spaces
      TOTL            observe upper bound on total probability;

* minimize
  OBJ..
      Z =E= SUM((C,A)$(ORD(C) GE ORD(A)), ZP(C,A)+ZM(C,A));

* subject to
  PROB(C,A)$(ORD(C) GE ORD(A) AND ORD(C) GT 1)..
      ZP(C,A) - ZM(C,A) =E=
*
      -P(C,A)*
      (LAMBDA$(ORD(C) LE B) +
      ALPHA*(ORD(C)-ORD(A)) +
      BETA*(ORD(A)-1) +
      MU*(ORD(C)-1))+
*
      P(C,A-1)*ALPHA*(ORD(C)-ORD(A)+1)+
*
      P(C,A+1)*(BETA*ORD(A))+
*
      P(C+1,A)*(MU*(ORD(C)-ORD(A)+1))+
*
      P(C+1,A+1)*((MU*ORD(A))$(ORD(C) LE B))+
*
      P(C-1,A-1)*LAMBDA ;

  NULL(C,A)$(ORD(C) LT ORD(A))..
      P(C,A) =E= 0;

  TOTL..
      SUM((C,A)$(ORD(C) GE ORD(A)),P(C,A)) =E= TOTPROB;


  MODEL P1 /ALL/;
  SOLVE P1 USING LP MINIMIZING Z;

*---------------------REPORTS--------------------------------------
*print the optimal objective value and solution.
 DISPLAY Z.L, P.L;
```

A / C	0	1	2	3
0	0.374992			
1	0.242957	0.132046		
2	0.078704	0.085551	0.023248	
3	0.016997	0.027713	0.015062	0.002729

APPENDIX B

The following GAMS program computes limiting probabilities for the multiplexer model system. Results shown are for a three-channel system with the following characteristics:

Maximum number of calls allowed equals 5.

Mean call length (μ^{-1}) of 3 minutes (180 seconds).

Load (λ/μ) equal to 1.

Mean talkspurt length (β^{-1}) of 352 ms (.352 seconds)

Mean length of silence (α^{-1}) of 650 ms.

Speech activity of 35% ($\alpha \div (\alpha + \beta) = 0.35$).

```
*------------GAMS AND DOLLAR CONTROL OPTIONS-----------------------
*                  (SEE APPENDICE B & C)


OPTIONS
    LIMCOL =  0   , LIMROW  = 0    , SOLPRINT = OFF , DECIMALS = 6
    RESLIM =  100, ITERLIM = 10000, OPTCR    = 0.1 , SEED     = 3141;

*-------------DEFINITIONS AND DATA---------------------------------
  SET
     C   cellers /0*5/
     A   talkspurts /0*3/;

  SCALARS
     alpha  talkspurt arrival rate in SEC(inverse) /1.53846/
     betam  talkspurt departure rate in SEC(inverse)  /6.993/
     s      service rate /3/
     lambda  customer arrival rate in SEC(inverse) /.005556/
     mu      customer departure rate in SEC(inverse) /0.005556/
     totprob  /1/
     K      maximum number of cells /5/
     J      maximum number of active cells /3/;

*------------------MODEL-------------------------------------------
  POSITIVE VARIABLES
      P(C,A)    limiting probability that system is in that state
      ZP(C,A)   z-plus dummy variable
      ZM(C,A)   z-minus dummy variable;

  VARIABLE
      Z          objective function to be minimized;

  EQUATIONS
      OBJ            dummy variables
      PROB(C,A)      calculate limiting probabilities
      NULL(C,A)      delete infeasible state spaces
      TOTL           observe upper bound on total probability;

* minimize
  OBJ..
      Z =E= SUM((C,A)$(ORD(C) GE ORD(A)), ZP(C,A)+ZM(C,A));

* subject to
  PROB(C,A)$(ORD(C) GE ORD(A) AND ORD(C) GT 1)..
      ZP(C,A) - ZM(C,A) =E=
*
      -P(C,A)*
      (LAMBDA$(ORD(C) LE K) +
      ALPHA*(ORD(C)-ORD(A))$(ORD(A) LE J)+
      BETAM*(ORD(A)-1)*S +
      MU*(ORD(C)-1))+
*
      P(C,A-1)*ALPHA*(ORD(C)-ORD(A)+1)+
*
      P(C,A+1)*(BETAM*ORD(A)*S)+
*
      P(C+1,A)*(MU*(ORD(C)-ORD(A)+1))+
*
      P(C+1,A+1)*((MU*ORD(A))$(ORD(C) LE K))+
*
      P(C-1,A-1)*LAMBDA ;

  NULL(C,A)$(ORD(C) LT ORD(A))..
      P(C,A) =E= 0;

  TOTL..
      SUM((C,A)$(ORD(C) GE ORD(A)),P(C,A)) =E= TOTPROB;

  MODEL MUX /ALL/;
  SOLVE MUX USING LP MINIMIZING Z;

*-------------------REPORTS-----------------------------------------
*print the optimal objective value and solution.
 DISPLAY Z.L, P.L ;
```

A / C	0	1	2	3
0	0.368137			
1	0.342869	0.025235		
2	0.159666	0.023502	0.000865	
3	0.049569	0.010949	0.000806	0.000020
4	0.011536	0.003396	0.000375	0.000018
5	0.002147	0.000790	0.000116	

APPENDIX C

The following program may be used to solve limiting probabilities for the bivariate Erlang model by setting "COMPRESS" equal to 1, "RO" equal to B and "HEADER" equal to 0.

```
      ∇MATRIXM CD
[1]  ⍝ MATRIX FOR ADAPTIVE MULTIPLEXER
[2]   ⎕IO←1
[3]  ⍝ THIS PROGRAM USES MATRIX INVERSION TO COMPUTE
LIMITING
[4]  ⍝ PROBABILITIES FOR THE MULTIPLEXER MODEL.
[5]  ⍝ IT REQUIRES A VECTOR INPUT OF 8 ELEMENTS.
[6]  ⍝ LAM IS THE CALL INITIATION RATE.
[7]  ⍝ MU IS THE CALL TERMINATION RATE.
[8]  ⍝ ALPHA IS THE TALKSPURT INITIATION RATE.
[9]  ⍝ BETA IS THE TALSPURT TERMINATION RATE.
[10] ⍝ A IS MAX NUMBER OF ACTIVE CALLS
[11] ⍝ C IS MAX NUMBER OF CALLS IN PROGRESS
[12] ⍝ COMPRESS IS THE COMPRESSION RATE
[13] ⍝ FOR PACKETIZED TALKSPURTS.
[14] ⍝ HEADER IS THE PROPORTION OF HEADER INFO
[15] ⍝ TO MEAN TALKSPURT LENGTH.
[16] ⍝ B IS THE INCOMING RATE IN BITS/SEC.
[17]  LAM←CD[1]
[18]  MU←CD[2]
[19]  ALPHA←CD[3]
[20]  BETA←CD[4]
[21]  A←CD[5]
[22]  C←CD[6]
[23]  COMPRESS←CD[7]
[24]  HEADER←CD[8]
[25]  B←32000
[26] ⍝ RO IS THE RATIO OF THE INPUT TO OUTPUT
[27] ⍝ TRANSMISSION RATES x B.
[28]  RO←A×B
[29]  SIZE←(+/⍳(A+1))
[30]  SIZE←SIZE+((C-A)×(A+1))
[31]  M←(SIZE,SIZE)⍴0
[32] ⍝ PROCESSOR SHARING SERVICE
[33] ⍝ BETAM IS THE TALKSPURT TERMINATION RATE AFTER
[34] ⍝ ACCOUNTING FOR COMPRESSION AND HEADER.
[35]  INVBETAM←((1÷COMPRESS)+HEADER)×B×INVBETA←1÷BETA
[36]  BETAM←1÷INVBETAM
[37]  SERV←BETAM×RO
```

```
  M[1;1]←0
  M[1;3]←LAM
  CC←0
  FINISH←1
 ITER:
  START←FINISH+1
  CC←CC+1
  LEV←CC
  →REACHA×⍳(LEV=A)
  →LARGA×⍳(LEV>A)
  NUMB←LEV+1
  FINISH←START+(NUMB-1)
  ML←((LEV+1),LEV)⍴0
  MM←((LEV+1),(LEV+1))⍴0
  MR←((LEV+1),(LEV+2))⍴0
  →NEXTMA
 ⍝ NUMB OF CALLS IN PROGRESS = MAX NUMB OF ACTIVE CALLS
A
 REACHA:
  NUMB←A+1
  FINISH←START+(NUMB-1)
  MR←MM←((A+1),(A+1))⍴0
  ML←((A+1),A)⍴0
  →NEXTMA
 ⍝ NUMB OF CALLS IN PROG > MAX NUMB OF ACTIVE CALLS
 LARGA:
  NUMB←A+1
  FINISH←START+(NUMB-1)
  MR←MM←ML←((A+1),(A+1))⍴0
 NEXTMA:
  CC1←0
 INNERR:
  →OUTR×⍳(CC1=(LEV+1))
  CC1←CC1+1
  →INNERR1×⍳(CC1=(LEV+1))
  ML[CC1;CC1]←(LEV-(CC1-1))×MU
 INNERR1:
  →INNERR2×⍳(CC1=1)
  ML[CC1;(CC1-1)]←(CC1-1)×MU
 INNERR2:
  →INNERR×⍳(CC1<(⍴ML)[1])
 OUTR:
  CM←0
 INNERM:
  →OUTM×⍳(CM>A+1)
  CM←CM+1
```

```
[83]   →NEXTM1×⍳(CM=(ρMM)[1])
[84]   MM[CM;CM+1]←(LEV-(CM-1))×ALPHA
[85]  NEXTM1:
[86]   →NEXTM×⍳(CM=1)
[87]   MM[CM;CM-1]←SERV×(CM-1)
[88]  NEXTM:
[89]   →INNERM×⍳(CM<(ρMM)[1])
[90]  OUTM:
[91]   CL←0
[92]  INNERL:
[93]   →OUTL×⍳(CL≥A)
[94]   CL←CL+1
[95]   MR[CL;(CL+1)]←LAM
[96]   →INNERL×⍳(CL<(ρML)[1])
[97]  OUTL:
[98]   START1←START-1
[99]   →CEQA×⍳(LEV=A)
[100]   →CBIGA×⍳(LEV>A)
[101]   M[START1+(⍳NUMB);(START1+(⍳NUMB))]←MM
[102]  M[START1+(⍳NUMB);(START-NUMB)+⍳(NUMB-1)]←ML
[103]  →END×⍳(CC=C)
[104]  M[START1+(⍳NUMB);(START1+NUMB+(⍳NUMB+1))]←MR
[105]  →ITER×⍳(CC<C)
[106]CEQA:
[107]  M[START1+(⍳NUMB);(START1+(⍳NUMB))]←MM
[108]  M[START1+(⍳NUMB);(START-NUMB)+⍳(NUMB-1)]←ML
[109]  →END×⍳(CC=C)
[110]  M[START1+(⍳NUMB);(START1+NUMB+(⍳NUMB))]←MR
[111]  →ITER×⍳(CC<C)
[112]CBIGA:
[113]  M[START1+(⍳NUMB);(START1+(⍳NUMB))]←MM
[114]  M[START1+(⍳NUMB);(START1-NUMB)+⍳NUMB]←ML
[115]  →END×⍳(CC=C)
[116]  M[START1+(⍳NUMB);(START1+NUMB+(⍳NUMB))]←MR
[117]  →ITER×⍳(CC<C)
[118]END:
[119]  IDENT←(⍳SIZE)∘.=(⍳SIZE)
[120]  IDENT←IDENT×((SIZE,SIZE)ρ(+/M))
[121]  MI←M←M-IDENT
[122]  M[;1]←1
[123]  LHS←(1,SIZE)ρ(1,((SIZE-1)ρ0))
[124]  PIA←LHS+.×(⌹M)
[125]  MATRIX←⍉(3,(ρ,PIA))ρSC,SA,(,PIA)
       ∇
```

APPENDIX D

The APL program APPROX calculates the limiting probabilities for both the Erlang and multiplexer models using approximation techniques. It calls the routine STATES to help format the output. BLOCK is used to compute the inner, outer, and combined inner-outer blocking probabilities for both the approximation (APPROX) and the actual (MATRIXM) calculations for comparison.

```
      ∇APPROX CMM
[1]    ⎕IO←1
[2]   ⍝ THIS PROGRAM REQUIRES A VECTOR OF 8 ELEMENTS AS
INPUT.
[3]   ⍝ IT CALCULATES THE LIMITING PROBABILITIES FOR THE
MULTIPLEXER
[4]   ⍝ AND ERLANG MODELS USING MATRIX INVERSION.
[5]   ⍝ L IS LAMBDA, THE CALL INITIATION RATE.
[6]   ⍝ M IS MU, THE CALL TERMINATION RATE.
[7]   ⍝ ALPHA IS THE TALKSPURT INITIATION RATE.
[8]   ⍝ BETA IS THE TALKSPURT TERMINATION RATE.
[9]   ⍝ A IS THE NUMBER OF CHANNELS.
[10]  ⍝ C IS THE MAXIMUM NUMBER OF CALLS ALLOWED.
[11]  ⍝ COMPRESS IS THE COMPRESSION RATE OF PACKETIZED
TALKSPURTS.
[12]  ⍝ HEADER IS THE PROPORTION OF HEADER INFORMATION TO
[13]  ⍝ MEAN LENGTH OF TALKSPURT.
[14]  ⍝ B IS THE INCOMING RATE IN BITS/SEC.
[15]   L←CMM[1]
[16]   M←CMM[2]
[17]   ALPHA←CMM[3]
[18]   BETA←CMM[4]
[19]   A←CMM[5]
[20]   C←CMM[6]
[21]   COMPRESS←CMM[7]
[22]   HEADER←CMM[8]
[23]   B←32000
[24]   RO←A×B
[25]  ⍝ CALCULATION FOR BINOMIAL PROB. OF J TALKSPURTS GIVEN
K CHANNELS
[26]  ⍝ FOR ERLANG
[27]   ⎕IO←0
[28]  ⍝DIM←(A+1),(A+1)
[29]  ⍝PRA←DIM⍴0
[30]  ⍝A1←ALPHA÷ALPHA+BETA
[31]  ⍝A2←BETA÷ALPHA+BETA
```

```
[32] ⍝K←0
[33] ⍝J←⍳A+1
[34] ⍝INLP:PRA[K;J]←(J!K)×(A1*J)×(A2*(K-J))
[35] ⍝K←K+1
[36] ⍝→(K≤A)/INLP
[37] ⍝ FOR MUX
[38] ⍝ INVBETAM IS THE NEW TALKSPURT LENGTH IN BITS
[39] ⍝ AFTER COMPRESSION AND HEADER ARE CONSIDERED.
[38]  INVBETAM←((1÷COMPRESS)+HEADER)×B×INVBETA←1÷BETA
[39]  BETAM←(1÷INVBETAM)
[40]  SERV←BETAM×RO
[41]  DIMM←(C+1),(A+1)
[42]  PRAM←DIMMρ0
[43]  K←0
[44]  J←⍳A+1
[45] INLPM:PRAM[K;J]←(J!K)×((ALPHA÷SERV)*J)
[46]  K←K+1
[47]  →(K≤C)/INLPM
[48]  PO←((A+1),(C+1))ρ1÷(+/PRAM)
[49]  PRAM←⍉PO×⍉PRAM
[50] ⍝ TRUNCATED POISSON PROBABILITY OF K CALLERS
[51] ⍝ GIVEN MAX J CHANNELS
[52] ⍝ FOR ERLANG (MAX CHANNELS = MAX CALLERS = A)
[53]  LOAD←L÷M
[54] ⍝K←⍳A+1
[55] ⍝PRC←(LOAD*K)÷!K
[56] ⍝PRCE←PRC÷(+/PRC)
[57] ⍝ALPE←PRA×⍉DIMρPRCE
[58] ⍝APOUTBLE←+/ALPE[A;]
[59] ⍝ FOR MUX (MAX CHANNELS = A, MAX CALLERS = C)
[60] ⍝K←(⍳C-A)+A+1
[61] ⍝PIO←PRC,(LOAD*K)÷!K
[62]  K←⍳C+1
[63]  PIO2←(C+1)ρ1
[64]  I←0
[65] MKPIO:X←1
[66] MKPIO2:PIO2[I]←(LOAD÷X)×PIO2[I]
[67]  X←X+1
[68]  →(X≤K[I])/MKPIO2
[69]  I←I+1
[70]  →(I≤C)/MKPIO
[71] ⍝PRCM←PIO÷+/PIO
[72]  PRCM2←PIO2÷+/PIO2
[73]  DIMM2←(A+1),(C+1)
[74] ⍝ALPM←PRAM×⍉DIMM2ρPRCM
[75] ⍝ FORM MATRIX OUTPUT
```

```
[76] ⍝STATES(A,C)
[77] ⍝ALPE←(,ALPE>0)/,ALPE
[78] ⍝ALPM←(,ALPM>0)/,ALPM
[79] ⍝ALPE←ALPE,((⍴SA)-(⍴ALPE))⍴0⍝
[80] ⍝ALPM←ALPM,((⍴SA)-(⍴ALPM))⍴0
[81] ⍝MATRIXAP←⍉(4,(⍴SA))⍴SC,SA,(ALPE),(ALPM)
[82]  ⎕IO←1
     ∇

      ∇STATES CM
[1]   ⍝ THIS FUNCTION RETURNS 2 VECTORS WHICH,
[2]   ⍝ TOGETHER, GIVE THE STATES IN TERMS OF
[3]   ⍝ NUMBER OF CALLS AND ACTIVE CALLS (C,A)
[4]    ⎕IO←1
[5]    A←CM[1]
[6]    C←CM[2]
[7]    VV←0,⍳A
[8]    SA←⍳0
[9]    SC←⍳0
[10]   SA←SA,0
[11]   SC←SC,0
[12]   LEV←0
[13]  ITERS:
[14]   LEV←LEV+1
[15]   SA←SA,(VV[⍳(LEV+1)])
[16]   SC←SC,((LEV+1)⍴LEV)
[17]   →ITERS×⍳(LEV<A)
[18]   →END×⍳(A=C)
[19]  ITERB:
[20]   LEV←LEV+1
[21]   SA←SA,VV
[22]   SC←SC,((⍴VV)⍴LEV)
[23]   →ITERB×⍳(LEV<C)
[24]  END:
     ∇
      ∇BLOCK CM
[1]    APPROX CM
[2]    MATRIXM CM
[3]    INBL←+/(SA=A)/,PIA
[4]    OUTBL←+/(SC=C)/,PIA
[5]    INOUTBL←INBL+OUTBL-¯1↑,PIA
[6]    INBLA←+/(SA=A)/ALPM
[7]    OUTBLA←+/(SC=C)/ALPM
[8]    INOUTBLA←INBLA+OUTBLA-¯1↑ALPM
[9]    MATRIX2←⍉(4,(⍴,PIA))⍴SC,SA,(ALPM),(,PIA)
     ∇
```

APPENDIX E

These tables compare actual outer and inner blocking probabilities (OUTBL, INBL) with their approximated counterparts (OUTBLA, INBLA). Results are shown for C (maximum number of calls allowed) equal to 5, 10, 15, 20, and 30. The values for A indicate the number of available channels.

The level of speech activity (average proportion of time a call of infinite duration is active) is assumed to be 35% for all runs. The mean length of a call is 3 minutes. The mean length of a talkspurt (β^{-1}) is 352 ms. The compression factor is 4-to-1 and the length of the header information is 15.625% of the mean length of a talkspurt. The rate of each active incoming channel is b = 32 Kbps. Thus, the value of $(\beta^{-1})^*$ is 4576 bits. The outgoing channel rate s is equal to A, the number of available channels, multiplied by b, the incoming channel rate. The values for load (λ/μ) are as indicated in the tables.

C = 5 A = 1

LOAD	OUTBL	OUTBLA	INBL	INBLA
1.0	.000600	.003067	.139541	.155796
2.0	.008525	.036697	.228909	.268848
3.0	.031201	.110054	.291287	.344872
4.0	.067800	.199067	.336466	.393533

C = 5 A = 2

LOAD	OUTBL	OUTBLA	INBL	INBLA
1.0	.002817	.003067	.004368	.004396
2.0	.033933	.036697	.014415	.014638
3.0	.102803	.110054	.025236	.025672
4.0	.187823	.199067	.034265	.034802

C = 5 A = 3

LOAD	OUTBL	OUTBLA	INBL	INBLA
1.0	.003063	.003067	.000047	.000046
2.0	.036645	.036697	.000272	.000269
3.0	.109912	.110054	.000606	.000601
4.0	.198840	.199067	.000935	.000926

C = 5 A = 4

LOAD	OUTBL	OUTBLA	INBL	INBLA
1.0	.003067	.003067	.000000	.000000
2.0	.036697	.036697	.000002	.000002
3.0	.110054	.110054	.000005	.000005
4.0	.199066	.199067	.000009	.000009
5.0	.284866	.284868	.000012	.000012

C = 5 A = 5

LOAD	OUTBL	OUTBLA	INBL	INBLA
1.0	.003067	.003067	.000000	.000000
2.0	.036697	.036697	.000000	.000000
3.0	.110054	.110054	.000000	.000000
4.0	.199067	.199067	.000000	.000000

C = 10 A = 1

LOAD	OUTBL	OUTBLA	INBL	INBLA
1.0	.000000	.000000	.139563	.156043
2.0	.000000	.000038	.229440	.274026
3.0	.000002	.000810	.293849	.365335
4.0	.000022	.005308	.343124	.437013
5.0	.000106	.018385	.382511	.493130
6.0	.000361	.043142	.414993	.536284
7.0	.000952	.078741	.442406	.568775
8.0	.002097	.121661	.465946	.592908
9.0	.004034	.167963	.486426	.610788

C = 10 A = 2

LOAD	OUTBL	OUTBLA	INBL	INBLA
1.0	.000000	.000000	.004417	.004454
2.0	.000018	.000038	.015691	.016187
3.0	.000390	.000810	.031280	.033097
4.0	.002651	.005308	.049188	.053231
5.0	.009672	.018385	.067782	.074441
6.0	.024096	.043142	.085720	.094647
7.0	.046763	.078741	.102057	.112434
8.0	.076569	.121661	.116316	.127276
9.0	.111361	.167963	.128415	.139294

C = 10 A = 3

LOAD	OUTBL	OUTBLA	INBL	INBLA
1.0	.000000	.000000	.000050	.000050
2.0	.000036	.000038	.000373	.000371
3.0	.000773	.000810	.001165	.001161
4.0	.005068	.005308	.002505	.002503
5.0	.017601	.018385	.004306	.004312
6.0	.041446	.043142	.006346	.006362
7.0	.075951	.078741	.008387	.008408
8.0	.117754	.121661	.010262	.010282
9.0	.163122	.167963	.011900	.011913

C = 10 A = 4

LOAD	OUTBL	OUTBLA	INBL	INBLA
1.0	.000000	.000000	.000000	.000000
2.0	.000038	.000038	.000004	.000004
3.0	.000809	.000810	.000021	.000021
4.0	.005300	.005308	.000059	.000058
5.0	.018359	.018385	.000122	.000120
6.0	.043085	.043142	.000203	.000200
7.0	.078645	.078741	.000291	.000288
8.0	.121526	.121661	.000378	.000374
9.0	.167793	.167963	.000458	.000453

C = 10 A = 5

LOAD	OUTBL	OUTBLA	INBL	INBLA
1.0	.000000	.000000	.000000	.000000
2.0	.000038	.000038	.000000	.000000
3.0	.000810	.000810	.000000	.000000
4.0	.005307	.005308	.000001	.000001
5.0	.018384	.018385	.000002	.000002
6.0	.043141	.043142	.000003	.000003
7.0	.078739	.078741	.000005	.000005
8.0	.121659	.121661	.000007	.000007
9.0	.167960	.167963	.000009	.000009

C = 15 A = 1

LOAD	OUTBL	OUTBLA	INBL	INBLA
5.0	.000000	.000157	.382516	.496189
6.0	.000000	.000892	.415014	.544033
7.0	.000000	.003319	.442467	.583626
8.0	.000000	.009101	.466091	.616453
9.0	.000001	.019868	.486723	.643499
10.0	.000003	.036497	.504960	.665527
11.0	.000008	.058797	.521245	.683244
12.0	.000018	.085729	.535910	.697359
13.0	.000037	.115865	.549215	.708549

C = 15 A = 2

LOAD	OUTBL	OUTBLA	INBL	INBLA
5.0	.000019	.000157	.068656	.076777
6.0	.000116	.000892	.088285	.101180
7.0	.000475	.003319	.107725	.126049
8.0	.001456	.009101	.126616	.150441
9.0	.003596	.019868	.144696	.173431
10.0	.007514	.036497	.161762	.194273
11.0	.013778	.058797	.177653	.212531
12.0	.022766	.085729	.192256	.228107
13.0	.034601	.115865	.205512	.241158

C = 15 A = 3

LOAD	OUTBL	OUTBLA	INBL	INBLA
5.0	.000124	.000157	.004685	.004725
6.0	.000707	.000892	.007487	.007605
7.0	.002654	.003319	.010934	.011183
8.0	.007362	.009101	.014887	.015308
9.0	.016292	.019868	.019132	.019737
10.0	.030380	.036497	.023430	.024196
11.0	.049703	.058797	.027567	.028446
12.0	.073562	.085729	.031592	.032330
13.0	.100820	.115865	.034826	.035773

C = 15 A = 4

LOAD	OUTBL	OUTBLA	INBL	INBLA
5.0	.000155	.000157	.000149	.000148
6.0	.000879	.000892	.000291	.000288
7.0	.003273	.003319	.000499	.000495
8.0	.008981	.009101	.000775	.000767
9.0	.019621	.019868	.001103	.001093
10.0	.036070	.036497	.001462	.001449
11.0	.058159	.058797	.001828	.001812
12.0	.084872	.085729	.002182	.002163
13.0	.114800	.115865	.002509	.002487

C = 15 A = 5

LOAD	OUTBL	OUTBLA	INBL	INBLA
5.0	.000157	.000157	.000003	.000003
6.0	.000891	.000892	.000007	.000006
7.0	.003317	.003319	.000013	.000013
8.0	.009097	.009101	.000023	.000022
9.0	.019860	.019868	.000035	.000034
10.0	.036482	.036497	.000049	.000049
11.0	.058774	.058797	.000065	.000064
12.0	.085698	.085729	.000081	.000079
13.0	.115826	.115865	.000095	.000094

C = 20 A = 1

LOAD	OUTBL	OUTBLA	INBL	INBLA
10.0	.000000	.001869	.504960	.671318
11.0	.000000	.004640	.521245	.692619
12.0	.000000	.009796	.535911	.710936
13.0	.000000	.018110	.549217	.726588
14.0	.000000	.030035	.561365	.739840
15.0	.000000	.045593	.572518	.750952
16.0	.000000	.064411	.582809	.760194
17.0	.000000	.085860	.592346	.767834
18.0	.000000	.109213	.601218	.774134

C = 20 A = 2

LOAD	OUTBL	OUTBLA	INBL	INBLA
10.0	.000041	.001869	.162731	.202251
11.0	.000122	.004640	.179552	.226056
12.0	.000307	.009796	.195578	.248492
13.0	.000687	.018110	.210814	.269187
14.0	.001383	.030035	.225270	.287860
15.0	.002552	.045593	.238957	.304366
16.0	.004371	.064411	.251880	.318709
17.0	.007017	.085860	.264043	.331011
18.0	.010655	.109213	.275449	.341472

C = 20 A = 3

LOAD	OUTBL	OUTBLA	INBL	INBLA
10.0	.001019	.001869	.025455	.026948
11.0	.002598	.004640	.031223	.033336
12.0	.005655	.009796	.037253	.040022
13.0	.010813	.018110	.043376	.046764
14.0	.018579	.030035	.049423	.053321
15.0	.029229	.045593	.055238	.059497
16.0	.042758	.064411	.060703	.065160
17.0	.058914	.085860	.065737	.070243
18.0	.077278	.109213	.070304	.074738

C = 20 A = 4

LOAD	OUTBL	OUTBLA	INBL	INBLA
10.0	.001767	.001869	.001807	.001800
11.0	.004394	.004640	.002464	.002458
12.0	.009299	.009796	.003216	.003212
13.0	.017239	.018110	.004036	.004034
14.0	.028677	.030035	.004888	.004887
15.0	.043667	.045593	.005736	.005735
16.0	.061882	.064411	.006552	.006549
17.0	.082738	.085860	.007316	.007309
18.0	.105538	.109213	.008017	.008004

C = 20 A = 5

LOAD	OUTBL	OUTBLA	INBL	INBLA
10.0	.001863	.001869	.000071	.000070
11.0	.004626	.004640	.000106	.000105
12.0	.009768	.009796	.000150	.000148
13.0	.018061	.018110	.000201	.000198
14.0	.029958	.030035	.000256	.000252
15.0	.045483	.045593	.000313	.000308
16.0	.064265	.064411	.000370	.000365
17.0	.085678	.085860	.000425	.000419
18.0	.108997	.109213	.000476	.000470

C = 20 A = 6

LOAD	OUTBL	OUTBLA	INBL	INBLA
10.0	.001869	.001869	.000002	.000002
11.0	.004640	.004640	.000003	.000003
12.0	.009795	.009796	.000004	.000004
13.0	.018108	.018110	.000006	.000006
14.0	.030033	.030035	.000008	.000008
15.0	.045589	.045593	.000011	.000010
16.0	.064406	.064411	.000013	.000013
17.0	.085854	.085860	.000015	.000015
18.0	.109205	.109213	.000017	.000017

C = 30 A = 1

LOAD	OUTBL	OUTBLA	INBL	INBLA
10.0	.000000	.000000	.504960	.671565
20.0	.000000	.008457	.617259	.807340
30.0	.000000	.132460	.674998	.849465

C = 30 A = 2

LOAD	OUTBL	OUTBLA	INBL	INBLA
15.0	.000000	.000221	.239302	.316978
16.0	.000000	.000564	.252495	.337216
17.0	.000000	.001281	.265068	.356489
18.0	.000000	.002622	.277059	.374743
19.0	.000001	.004902	.288505	.391912
20.0	.000003	.008457	.299441	.407918
21.0	.000005	.013594	.309900	.422690
22.0	.000011	.020535	.319911	.436175
23.0	.000022	.029386	.329505	.448352
24.0	.000040	.040121	.338705	.459238
25.0	.000070	.052603	.347537	.468885
26.0	.000119	.066612	.356022	.477375
27.0	.000194	.081880	.364180	.484809
28.0	.000307	.098122	.372028	.491296
29.0	.000471	.115065	.379582	.496948

C = 30 A = 3

LOAD	OUTBL	OUTBLA	INBL	INBLA
15.0	.000024	.000221	.058605	.066333
16.0	.000066	.000564	.065968	.075567
17.0	.000161	.001281	.073451	.085073
18.0	.000354	.002622	.081003	.094737
19.0	.000719	.004902	.088577	.104422
20.0	.001352	.008457	.096125	.113980
21.0	.002379	.013594	.103599	.123255
22.0	.003942	.020535	.110949	.132106
23.0	.006193	.029386	.118123	.140417
24.0	.009278	.040121	.125073	.148106
25.0	.013321	.052603	.131753	.155129
26.0	.018412	.066612	.138123	.161476
27.0	.024603	.081880	.144154	.167165
28.0	.031901	.098122	.149823	.172234
29.0	.040272	.115065	.155118	.176733

C = 30 A = 4

LOAD	OUTBL	OUTBLA	INBL	INBLA
15.0	.000157	.000221	.007023	.007137
16.0	.000404	.000564	.008581	.008760
17.0	.000926	.001281	.010306	.010568
18.0	.001916	.002622	.012184	.012543
19.0	.003626	.004902	.014190	.014657
20.0	.006340	.008457	.016291	.016869
21.0	.010336	.013594	.018447	.019130
22.0	.015848	.020535	.020616	.021390
23.0	.023025	.029386	.022755	.023600
24.0	.031915	.040121	.024828	.025719
25.0	.042465	.052603	.026804	.027718
26.0	.054539	.066612	.028661	.029577
27.0	.067940	.081880	.030388	.031285
28.0	.082440	.098122	.031979	.032842
29.0	.097799	.115065	.033433	.034252

C • 30   A • 5

LOAD	OUTBL	OUTBLA	INBL	INBLA
15.0	.000214	.000221	.000451	.000446
16.0	.000547	.000564	.000594	.000588
17.0	.001241	.001281	.000766	.000758
18.0	.002544	.002622	.000965	.000955
19.0	.004760	.004902	.001191	.001180
20.0	.008222	.008457	.001439	.001426
21.0	.013231	.013594	.001705	.001690
22.0	.020013	.020535	.001981	.001964
23.0	.028677	.029386	.002260	.002242
24.0	.039206	.040121	.002537	.002516
25.0	.051474	.052603	.002805	.002782
26.0	.065268	.066612	.003061	.003035
27.0	.080329	.081880	.003302	.003273
28.0	.096377	.098122	.003525	.003493
29.0	.113144	.115065	.003722	.003697

C • 30   A • 6

LOAD	OUTBL	OUTBLA	INBL	INBLA
15.0	.000221	.000221	.000018	.000018
16.0	.000563	.000564	.000026	.000026
17.0	.001278	.001281	.000036	.000035
18.0	.002617	.002622	.000048	.000047
19.0	.004893	.004902	.000062	.000061
20.0	.008443	.008457	.000078	.000077
21.0	.013571	.013594	.000096	.000094
22.0	.020502	.020535	.000115	.000113
23.0	.029340	.029386	.000135	.000133
24.0	.040062	.040121	.000156	.000153
25.0	.052530	.052603	.000176	.000173
26.0	.066525	.066612	.000196	.000192
27.0	.081778	.081880	.000214	.000211
28.0	.098007	.098122	.000232	.000228
29.0	.114938	.115065	.000249	.000244

C • 30   A • 7

LOAD	OUTBL	OUTBLA	INBL	INBLA
15.0	.000221	.000221	.000001	.000001
16.0	.000564	.000564	.000001	.000001
17.0	.001281	.001281	.000001	.000001
18.0	.002622	.002622	.000002	.000002
19.0	.004902	.004902	.000002	.000002
20.0	.008457	.008457	.000003	.000003
21.0	.013593	.013594	.000004	.000004
22.0	.020534	.020535	.000005	.000004
23.0	.029384	.029386	.000005	.000005
24.0	.040118	.040121	.000006	.000006
25.0	.052600	.052603	.000007	.000007
26.0	.066609	.066612	.000008	.000008
27.0	.081875	.081880	.000009	.000009
28.0	.098117	.098122	.000010	.000010
29.0	.115060	.115065	.000011	.000011

APPENDIX F

The following tables show results of the approximation to the multiplexer model when C (maximum number of calls allowed) equals 5, 10, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 125, 150, and 160. The values for A indicate the number of available channels.

Outer blocking probabilities are calculated from the formula for the truncated Poisson distribution (2). Inner blocking probabilities (equal to $P_J(k)$, from (6), where $J = A$) are compared for three different levels (28%, 35%, and 42%) of speech activity (average proportion of time a call of infinite duration is active). Mean talkspurt lengths (β^{-1}) are assumed to be 288 ms, 352 ms, and 420 ms, respectively, for the three levels of speech activity. The compression factor is 4-to-1 and the length of the header information is 15.625% of the mean length of a talkspurt. The rate of each active incoming channel is b = 32 Kbps. Thus, the values for $(\beta^{-1})^*$ are 3744, 4576, and 5460 bits, respectively, for the three levels of speech activity.

The mean length of a call is 3 minutes. The outgoing channel rate s is equal to A, the number of available channels, multiplied by b, the channel rate. The values for load (λ/μ) are as indicated in the tables.

BLOCKING PROBABILITIES FOR C = 5 A = 1

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
1.0	.003067	.121505	.155794	.190727
2.0	.032258	.188530	.236326	.283025
3.0	.099265	.251962	.311061	.367079
4.0	.186047	.300867	.367794	.429927

BLOCKING PROBABILITIES FOR C = 5 A = 2

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
1.0	.003067	.002460	.004396	.007169
2.0	.032258	.007323	.012868	.020597
3.0	.099265	.013315	.023156	.036636
4.0	.186047	.018826	.032526	.051083

BLOCKING PROBABILITIES FOR C = 5 A = 3

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
1.0	.003067	.000018	.000046	.000102
2.0	.032258	.000095	.000237	.000515
3.0	.099265	.000219	.000542	.001173
4.0	.186047	.000351	.000866	.001868

BLOCKING PROBABILITIES FOR C = 5 A = 4

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
1.0	.003067	.000000	.000000	.000001
2.0	.032258	.000000	.000002	.000005
3.0	.099265	.000001	.000005	.000014
4.0	.186047	.000002	.000008	.000024

BLOCKING PROBABILITIES FOR C = 5 A = 5

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
1.0	.003067	.000000	.000000	.000000
2.0	.032258	.000000	.000000	.000000
3.0	.099265	.000000	.000000	.000000
4.0	.186047	.000000	.000000	.000000

BLOCKING PROBABILITIES FOR C = 10 A = 3

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
1.0	.000000	.000020	.000050	.000109
2.0	.000034	.000133	.000327	.000700
3.0	.000737	.000438	.001056	.002217
4.0	.005030	.001000	.002372	.004896
5.0	.017896	.001791	.004197	.008540
6.0	.042590	.002706	.006281	.012637
7.0	.078266	.003627	.008357	.016671
8.0	.121312	.004475	.010253	.020319

BLOCKING PROBABILITIES FOR C = 10 A = 4

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
1.0	.000000	.000000	.000000	.000001
2.0	.000034	.000001	.000004	.000011
3.0	.000737	.000006	.000019	.000054
4.0	.005030	.000016	.000055	.000156
5.0	.017896	.000035	.000117	.000326
6.0	.042590	.000060	.000197	.000546
7.0	.078266	.000087	.000286	.000787
8.0	.121312	.000113	.000373	.001022

BLOCKING PROBABILITIES FOR C = 10 A = 5

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
1.0	.000000	.000000	.000000	.000000
2.0	.000034	.000000	.000000	.000000
3.0	.000737	.000000	.000000	.000001
4.0	.005030	.000000	.000001	.000003
5.0	.017896	.000000	.000002	.000007
6.0	.042590	.000001	.000003	.000013
7.0	.078266	.000001	.000005	.000020
8.0	.121312	.000002	.000007	.000027

BLOCKING PROBABILITIES FOR C = 10 A = 6

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
1.0	.000000	.000000	.000000	.000000
2.0	.000034	.000000	.000000	.000000
3.0	.000737	.000000	.000000	.000000
4.0	.005030	.000000	.000000	.000000
5.0	.017896	.000000	.000000	.000000
6.0	.042590	.000000	.000000	.000000
7.0	.078266	.000000	.000000	.000000
8.0	.121312	.000000	.000000	.000000

BLOCKING PROBABILITIES FOR C = 20 A = 3

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
5.0	.000000	.002036	.004729	.009533
6.0	.000004	.003348	.007640	.015101
7.0	.000030	.005059	.011344	.021995
8.0	.000159	.007182	.015833	.030130
9.0	.000617	.009715	.021066	.039367
10.0	.001869	.012627	.026948	.049504
11.0	.004640	.015855	.033336	.060265
12.0	.009796	.019295	.040022	.071301
13.0	.018110	.022822	.046764	.082230
14.0	.030035	.026301	.053321	.092694
15.0	.045593	.029618	.059497	.102417

BLOCKING PROBABILITIES FOR C = 20 A = 4

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
5.0	.000000	.000045	.000148	.000407
6.0	.000004	.000090	.000292	.000789
7.0	.000030	.000160	.000513	.001364
8.0	.000159	.000263	.000829	.002171
9.0	.000617	.000403	.001256	.003238
10.0	.001869	.000585	.001800	.004573
11.0	.004640	.000808	.002458	.006161
12.0	.009796	.001067	.003212	.007956
13.0	.018110	.001353	.004034	.009885
14.0	.030035	.001652	.004887	.011864
15.0	.045593	.001952	.005735	.013813

BLOCKING PROBABILITIES FOR C = 20 A = 5

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)

5.0	.000000	.000001	.000003	.000010
6.0	.000004	.000001	.000007	.000024
7.0	.000030	.000003	.000014	.000050
8.0	.000159	.000006	.000026	.000092
9.0	.000616	.000010	.000044	.000156
10.0	.001868	.000016	.000070	.000245
11.0	.004639	.000024	.000105	.000363
12.0	.009795	.000034	.000148	.000507
13.0	.018109	.000046	.000199	.000673
14.0	.030035	.000059	.000252	.000852
15.0	.045593	.000073	.000308	.001037

BLOCKING PROBABILITIES FOR C = 20 A = 6

LOAD	OUTER	INNER(29)	INNER(35)	INNER(42)
5.0	.000000	.000000	.000000	.000000
6.0	.000004	.000000	.000000	.000001
7.0	.000030	.000000	.000000	.000001
8.0	.000159	.000000	.000001	.000003
9.0	.000616	.000000	.000001	.000005
10.0	.001868	.000000	.000002	.000009
11.0	.004639	.000000	.000003	.000014
12.0	.009795	.000001	.000004	.000020
13.0	.018109	.000001	.000006	.000029
14.0	.030035	.000001	.000008	.000038
15.0	.045593	.000002	.000010	.000048

BLOCKING PROBABILITIES FOR C = 20 A = 7

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
5.0	.000000	.000000	.000000	.000000
6.0	.000004	.000000	.000000	.000000
7.0	.000030	.000000	.000000	.000000
8.0	.000159	.000000	.000000	.000000
9.0	.000616	.000000	.000000	.000000
10.0	.001868	.000000	.000000	.000000
11.0	.004639	.000000	.000000	.000000
12.0	.009795	.000000	.000000	.000001
13.0	.018109	.000000	.000000	.000001
14.0	.030035	.000000	.000000	.000001
15.0	.045593	.000000	.000000	.000001

BLOCKING PROBABILITIES FOR C = 25 A = 4

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
10.0	.000029	.000595	.001827	.004633
11.0	.000117	.000838	.002539	.006336
12.0	.000378	.001141	.003408	.008375
13.0	.001029	.001505	.004439	.010748
14.0	.002419	.001932	.005626	.013431
15.0	.005011	.002415	.006951	.016375
16.0	.009319	.002943	.008392	.019508
17.0	.015801	.003502	.009879	.022738
18.0	.024756	.004074	.011394	.025970
19.0	.036273	.004641	.012884	.029115
20.0	.050222	.005190	.014313	.032102

BLOCKING PROBABILITIES FOR C = 25 A = 5

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
10.0	.000029	.000017	.000073	.000253
11.0	.000117	.000026	.000112	.000385
12.0	.000378	.000039	.000165	.000561
13.0	.001029	.000055	.000234	.000785
14.0	.002419	.000076	.000320	.001062
15.0	.005011	.000102	.000423	.001389
16.0	.009319	.000131	.000542	.001760
17.0	.015801	.000164	.000672	.002165
18.0	.024756	.000199	.000809	.002589
19.0	.036273	.000234	.000950	.003019
20.0	.050222	.000270	.001089	.003443

BLOCKING PROBABILITIES FOR C = 25 A = 6

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
10.0	.000029	.000000	.000002	.000009
11.0	.000117	.000001	.000003	.000015
12.0	.000378	.000001	.000005	.000024
13.0	.001029	.000001	.000008	.000037
14.0	.002419	.000002	.000012	.000054
15.0	.005011	.000003	.000017	.000075
16.0	.009319	.000004	.000022	.000100
17.0	.015801	.000005	.000029	.000129
18.0	.024756	.000006	.000036	.000161
19.0	.036273	.000008	.000044	.000194
20.0	.050222	.000009	.000052	.000227

BLOCKING PROBABILITIES FOR C = 25 A = 7

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
10.0	.000029	.000000	.000000	.000000
11.0	.000117	.000000	.000000	.000000
12.0	.000378	.000000	.000000	.000001
13.0	.001029	.000000	.000000	.000001
14.0	.002419	.000000	.000000	.000002
15.0	.005011	.000000	.000000	.000003
16.0	.009319	.000000	.000001	.000004
17.0	.015801	.000000	.000001	.000005
18.0	.024756	.000000	.000001	.000007
19.0	.036273	.000000	.000001	.000008
20.0	.050222	.000000	.000002	.000010

BLOCKING PROBABILITIES FOR C = 25 A = 8

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
10.0	.000029	.000000	.000000	.000000
11.0	.000117	.000000	.000000	.000000
12.0	.000378	.000000	.000000	.000000
13.0	.001029	.000000	.000000	.000000
14.0	.002419	.000000	.000000	.000000
15.0	.005011	.000000	.000000	.000000
16.0	.009319	.000000	.000000	.000000
17.0	.015801	.000000	.000000	.000000
18.0	.024756	.000000	.000000	.000000
19.0	.036273	.000000	.000000	.000000
20.0	.050222	.000000	.000000	.000000

BLOCKING PROBABILITIES FOR C = 30 A = 4

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
15.0	.000221	.002490	.007137	.016743
16.0	.000564	.003097	.008760	.020247
17.0	.001281	.003784	.010568	.024080
18.0	.002622	.004547	.012543	.028193
19.0	.004902	.005375	.014657	.032522
20.0	.008457	.006253	.016869	.036983
21.0	.013594	.007162	.019130	.041481

22.0	.020535	.008079	.021390	.045920
23.0	.029386	.008986	.023600	.050214
24.0	.040121	.009863	.025719	.054290
25.0	.052603	.010696	.027718	.058099

BLOCKING PROBABILITIES FOR C = 30 A = 5

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
15.0	.000221	.000108	.000446	.001454
16.0	.000564	.000144	.000588	.001893
17.0	.001281	.000187	.000758	.002410
18.0	.002622	.000238	.000955	.003005
19.0	.004902	.000297	.001180	.003670
20.0	.008457	.000362	.001426	.004394
21.0	.013594	.000432	.001690	.005159
22.0	.020535	.000505	.001964	.005948
23.0	.029386	.000580	.002242	.006740
24.0	.040121	.000655	.002516	.007517
25.0	.052603	.000727	.002782	.008264

BLOCKING PROBABILITIES FOR C = 30 A = 6

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
15.0	.000221	.000003	.000018	.000081
16.0	.000564	.000004	.000026	.000114
17.0	.001281	.000006	.000035	.000154
18.0	.002622	.000008	.000047	.000204
19.0	.004902	.000011	.000061	.000262
20.0	.008457	.000013	.000077	.000328
21.0	.013594	.000017	.000094	.000402
22.0	.020535	.000020	.000113	.000480
23.0	.029386	.000024	.000133	.000561
24.0	.040121	.000027	.000153	.000642
25.0	.052603	.000031	.000173	.000723

BLOCKING PROBABILITIES FOR C = 30 A = 7

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
15.0	.000221	.000000	.000001	.000003
16.0	.000564	.000000	.000001	.000005
17.0	.001281	.000000	.000001	.000007
18.0	.002622	.000000	.000002	.000009
19.0	.004902	.000000	.000002	.000013
20.0	.008457	.000000	.000003	.000017
21.0	.013594	.000000	.000004	.000021
22.0	.020535	.000001	.000004	.000026
23.0	.029386	.000001	.000005	.000031
24.0	.040121	.000001	.000006	.000037
25.0	.052603	.000001	.000007	.000042

BLOCKING PROBABILITIES FOR C = 30 A = 8

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
15.0	.000221	.000000	.000000	.000000
16.0	.000564	.000000	.000000	.000000
17.0	.001281	.000000	.000000	.000000
18.0	.002622	.000000	.000000	.000000
19.0	.004902	.000000	.000000	.000000
20.0	.008457	.000000	.000000	.000001
21.0	.013594	.000000	.000000	.000001
22.0	.020535	.000000	.000000	.000001
23.0	.029386	.000000	.000000	.000001
24.0	.040121	.000000	.000000	.000001
25.0	.052603	.000000	.000000	.000002

BLOCKING PROBABILITIES FOR C = 30 A = 9

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
15.0	.000221	.000000	.000000	.000000
16.0	.000564	.000000	.000000	.000000
17.0	.001281	.000000	.000000	.000000
18.0	.002622	.000000	.000000	.000000
19.0	.004902	.000000	.000000	.000000
20.0	.008457	.000000	.000000	.000000
21.0	.013594	.000000	.000000	.000000
22.0	.020535	.000000	.000000	.000000
23.0	.029386	.000000	.000000	.000000
24.0	.040121	.000000	.000000	.000000
25.0	.052603	.000000	.000000	.000000

BLOCKING PROBABILITIES FOR C = 35 A = 4

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
20.0	.000686	.006502	.017432	.037996
21.0	.001393	.007584	.020082	.043181
22.0	.002616	.008748	.022889	.048580
23.0	.004578	.009981	.025818	.054123
24.0	.007514	.011263	.028823	.059726
25.0	.011646	.012572	.031854	.065301
26.0	.017149	.013884	.034859	.070759
27.0	.024128	.015177	.037789	.076020
28.0	.032606	.016429	.040601	.081018
29.0	.042527	.017624	.043263	.085704
30.0	.053771	.018751	.045752	.090049

BLOCKING PROBABILITIES FOR C = 35 A = 5

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
20.0	.000686	.000388	.001517	.004633
21.0	.001393	.000477	.001845	.005570
22.0	.002616	.000577	.002213	.006602
23.0	.004578	.000689	.002616	.007719
24.0	.007514	.000810	.003048	.008904
25.0	.011646	.000938	.003501	.010133
26.0	.017149	.001070	.003967	.011384
27.0	.024128	.001205	.004437	.012632
28.0	.032606	.001338	.004900	.013855
29.0	.042527	.001469	.005350	.015033
30.0	.053771	.001595	.005780	.016153

BLOCKING PROBABILITIES FOR C = 35 A = 6

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
20.0	.000686	.000015	.000085	.000360
21.0	.001393	.000019	.000108	.000456
22.0	.002616	.000025	.000136	.000568
23.0	.004578	.000031	.000168	.000694
24.0	.007514	.000037	.000203	.000834
25.0	.011646	.000045	.000242	.000984
26.0	.017149	.000052	.000283	.001142
27.0	.024128	.000060	.000325	.001305
28.0	.032606	.000069	.000367	.001468
29.0	.042527	.000077	.000410	.001629
30.0	.053771	.000085	.000451	.001785

BLOCKING PROBABILITIES FOR C = 35 A = 7

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
20.0	.000686	.000000	.000003	.000019
21.0	.001393	.000001	.000004	.000026
22.0	.002616	.000001	.000006	.000033
23.0	.004578	.000001	.000007	.000043
24.0	.007514	.000001	.000009	.000055
25.0	.011646	.000001	.000011	.000065
26.0	.017149	.000002	.000014	.000077
27.0	.024128	.000002	.000016	.000090
28.0	.032606	.000002	.000019	.000104
29.0	.042527	.000003	.000021	.000117
30.0	.053771	.000003	.000024	.000131

BLOCKING PROBABILITIES FOR C = 35 A = 8

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
20.0	.000686	.000000	.000000	.000001
21.0	.001393	.000000	.000000	.000001
22.0	.002616	.000000	.000000	.000001
23.0	.004578	.000000	.000000	.000002
24.0	.007514	.000000	.000000	.000002
25.0	.011646	.000000	.000000	.000003
26.0	.017149	.000000	.000000	.000004
27.0	.024128	.000000	.000001	.000004
28.0	.032606	.000000	.000001	.000005
29.0	.042527	.000000	.000001	.000006
30.0	.053771	.000000	.000001	.000007

BLOCKING PROBABILITIES FOR C = 35 A = 9

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
15.0	.000004	.000000	.000000	.000000
16.0	.000015	.000000	.000000	.000000
17.0	.000047	.000000	.000000	.000000
18.0	.000127	.000000	.000000	.000000
19.0	.000310	.000000	.000000	.000000
20.0	.000686	.000000	.000000	.000000
21.0	.001393	.000000	.000000	.000000
22.0	.002616	.000000	.000000	.000000
23.0	.004578	.000000	.000000	.000000
24.0	.007514	.000000	.000000	.000000
25.0	.011646	.000000	.000000	.000000
26.0	.017149	.000000	.000000	.000000
27.0	.024128	.000000	.000000	.000000
28.0	.032606	.000000	.000000	.000000
29.0	.042527	.000000	.000000	.000000
30.0	.053771	.000000	.000000	.000000

BLOCKING PROBABILITIES FOR C = 40 A = 4

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
25.0	.001411	.013125	.033008	.067203
26.0	.002497	.014726	.036606	.073619
27.0	.004170	.016393	.040298	.080102
28.0	.006605	.018135	.044039	.086578
29.0	.009971	.019838	.047780	.092967
30.0	.014409	.021567	.051470	.099192
31.0	.020017	.023268	.055061	.105183
32.0	.026838	.024917	.058512	.110879
33.0	.034864	.026497	.061788	.116238
34.0	.044032	.027993	.064866	.121229
35.0	.054244	.029397	.067731	.125840

BLOCKING PROBABILITIES FOR C = 40 A = 5

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
25.0	.001411	.001010	.003738	.010713
26.0	.002497	.001183	.004331	.012271
27.0	.004170	.001369	.004967	.013920
28.0	.006605	.001568	.005638	.015637
29.0	.009971	.001776	.006333	.017398
30.0	.014409	.001990	.007042	.019173
31.0	.020017	.002206	.007752	.020937
32.0	.026838	.002421	.008454	.022663
33.0	.034864	.002632	.009136	.024329
34.0	.044032	.002836	.009792	.025916
35.0	.054244	.003030	.010414	.027414

BLOCKING PROBABILITIES FOR C = 40 A = 6

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
20.0	.000028	.000015	.000086	.000364
21.0	.000072	.000020	.000111	.000465
22.0	.000170	.000026	.000141	.000586
23.0	.000371	.000032	.000177	.000728
24.0	.000748	.000040	.000220	.000893
25.0	.001411	.000050	.000269	.001081
26.0	.002497	.000061	.000324	.001292
27.0	.004170	.000073	.000386	.001525
28.0	.006605	.000086	.000454	.001777
29.0	.009971	.000101	.000526	.002044
30.0	.014409	.000116	.000602	.002321
31.0	.020017	.000132	.000680	.002605
32.0	.026838	.000148	.000759	.002889
33.0	.034864	.000164	.000837	.003169
34.0	.044032	.000179	.000913	.003442
35.0	.054244	.000194	.000987	.003705

BLOCKING PROBABILITIES FOR C = 40 A = 7

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
20.0	.000028	.000000	.000003	.000020
21.0	.000072	.000001	.000005	.000027
22.0	.000170	.000001	.000006	.000035
23.0	.000371	.000001	.000008	.000046
24.0	.000748	.000001	.000010	.000059
25.0	.001411	.000002	.000013	.000074
26.0	.002497	.000002	.000017	.000093
27.0	.004170	.000003	.000021	.000113
28.0	.006605	.000003	.000025	.000136
29.0	.009971	.000004	.000030	.000162
30.0	.014409	.000005	.000035	.000189
31.0	.020017	.000005	.000040	.000217
32.0	.026838	.000006	.000046	.000245
33.0	.034864	.000007	.000052	.000274
34.0	.044032	.000008	.000057	.000303
35.0	.054244	.000008	.000063	.000331

BLOCKING PROBABILITIES FOR C = 40 A = 8

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
20.0	.000028	.000000	.000000	.000001
21.0	.000072	.000000	.000000	.000001
22.0	.000170	.000000	.000000	.000002
23.0	.000371	.000000	.000000	.000002
24.0	.000748	.000000	.000000	.000003
25.0	.001411	.000000	.000000	.000004
26.0	.002497	.000000	.000001	.000005
27.0	.004170	.000000	.000001	.000006

28.0	.006605	.000000	.000001	.000008
29.0	.009971	.000000	.000001	.000009
30.0	.014409	.000000	.000001	.000011
31.0	.020017	.000000	.000002	.000013
32.0	.026838	.000000	.000002	.000015
33.0	.034864	.000000	.000002	.000017
34.0	.044032	.000000	.000003	.000019
35.0	.054244	.000000	.000003	.000021

BLOCKING PROBABILITIES FOR C = 40   A = 9

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
20.0	.000028	.000000	.000000	.000000
21.0	.000072	.000000	.000000	.000000
22.0	.000170	.000000	.000000	.000000
23.0	.000371	.000000	.000000	.000000
24.0	.000748	.000000	.000000	.000000
25.0	.001411	.000000	.000000	.000000
26.0	.002497	.000000	.000000	.000000
27.0	.004170	.000000	.000000	.000000
28.0	.006605	.000000	.000000	.000000
29.0	.009971	.000000	.000000	.000000
30.0	.014409	.000000	.000000	.000000
31.0	.020017	.000000	.000000	.000001
32.0	.026838	.000000	.000000	.000001
33.0	.034864	.000000	.000000	.000001
34.0	.044032	.000000	.000000	.000001
35.0	.054244	.000000	.000000	.000001

BLOCKING PROBABILITIES FOR C = 45   A = 4

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
28.0	.000767	.018530	.044868	.087856
29.0	.001369	.020499	.049061	.094929
30.0	.002320	.022545	.053353	.102059
31.0	.003744	.024649	.057708	.109188
32.0	.005775	.026792	.062084	.116253
33.0	.008546	.028948	.066432	.123186
34.0	.012171	.031092	.070708	.129921
35.0	.016742	.033198	.074864	.136399
36.0	.022310	.035244	.078863	.142568
37.0	.028890	.037210	.082670	.148388
38.0	.036458	.039080	.086262	.153833

BLOCKING PROBABILITIES FOR C = 45   A = 5

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
28.0	.000767	.001635	.005842	.016105
29.0	.001369	.001881	.006654	.018127
30.0	.002320	.002148	.007520	.020256
31.0	.003744	.002432	.008435	.022474
32.0	.005775	.002732	.009387	.024755
33.0	.008546	.003043	.010366	.027071
34.0	.012171	.003361	.011358	.029395
35.0	.016742	.003681	.012350	.031694
36.0	.022310	.004000	.013328	.033942
37.0	.028890	.004313	.014282	.036115
38.0	.036458	.004616	.015201	.038192

BLOCKING PROBABILITIES FOR C = 45   A = 6

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
28.0	.000767	.000092	.000482	.001871
29.0	.001369	.000110	.000570	.002192
30.0	.002320	.000130	.000669	.002545
31.0	.003744	.000152	.000776	.002926
32.0	.005775	.000176	.000891	.003331
33.0	.008546	.000202	.001013	.003756
34.0	.012171	.000229	.001140	.004195
35.0	.016742	.000256	.001270	.004641
36.0	.022310	.000284	.001401	.005087
37.0	.028890	.000312	.001532	.005528
38.0	.036458	.000340	.001660	.005958

BLOCKING PROBABILITIES FOR C = 45   A = 7

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
28.0	.000767	.000004	.000027	.000148
29.0	.001369	.000004	.000034	.000180
30.0	.002320	.000005	.000041	.000216
31.0	.003744	.000007	.000049	.000257
32.0	.005775	.000008	.000058	.000302
33.0	.008546	.000009	.000067	.000350
34.0	.012171	.000011	.000077	.000401
35.0	.016742	.000012	.000088	.000454
36.0	.022310	.000014	.000099	.000508
37.0	.028890	.000015	.000110	.000562
38.0	.036458	.000017	.000121	.000616

BLOCKING PROBABILITIES FOR C = 45   A = 8

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
28.0	.000767	.000000	.000001	.000008
29.0	.001369	.000000	.000001	.000011
30.0	.002320	.000000	.000002	.000013
31.0	.003744	.000000	.000002	.000016
32.0	.005775	.000000	.000003	.000020
33.0	.008546	.000000	.000003	.000023
34.0	.012171	.000000	.000004	.000027
35.0	.016742	.000000	.000004	.000031
36.0	.022310	.000000	.000005	.000036
37.0	.028890	.000001	.000006	.000040
38.0	.036458	.000001	.000006	.000045

BLOCKING PROBABILITIES FOR C = 45   A = 9

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
28.0	.000767	.000000	.000000	.000000
29.0	.001369	.000000	.000000	.000000
30.0	.002320	.000000	.000000	.000001
31.0	.003744	.000000	.000000	.000001
32.0	.005775	.000000	.000000	.000001
33.0	.008546	.000000	.000000	.000001
34.0	.012171	.000000	.000000	.000001
35.0	.016742	.000000	.000000	.000002
36.0	.022310	.000000	.000000	.000002
37.0	.028890	.000000	.000000	.000002
38.0	.036458	.000000	.000000	.000002

BLOCKING PROBABILITIES FOR C = 45   A = 10

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
28.0	.000767	.000000	.000000	.000000
29.0	.001369	.000000	.000000	.000000
30.0	.002320	.000000	.000000	.000000
31.0	.003744	.000000	.000000	.000000
32.0	.005775	.000000	.000000	.000000
33.0	.008546	.000000	.000000	.000000

34.0	.012171	.000000	.000000	.000000
35.0	.016742	.000000	.000000	.000000
36.0	.022310	.000000	.000000	.000000
37.0	.028890	.000000	.000000	.000000
38.0	.036458	.000000	.000000	.000000

BLOCKING PROBABILITIES FOR C = 50   A = 5

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
32.0	.000754	.002925	.009649	.025312
33.0	.001294	.003183	.010765	.027915
34.0	.002121	.003565	.011940	.030619
35.0	.003333	.003969	.013165	.033402
36.0	.005036	.004391	.014430	.036238
37.0	.007335	.004826	.015720	.039099
38.0	.010328	.005269	.017023	.041955
39.0	.014095	.005714	.018322	.044775
40.0	.018691	.006158	.019604	.047530
41.0	.024143	.006594	.020855	.050196
42.0	.030451	.007018	.022064	.052751

BLOCKING PROBABILITIES FOR C = 50   A = 6

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
32.0	.000754	.000186	.000934	.003465
33.0	.001294	.000217	.001078	.003962
34.0	.002121	.000250	.001236	.004497
35.0	.003333	.000287	.001406	.005067
36.0	.005036	.000326	.001587	.005667
37.0	.007335	.000368	.001776	.006290
38.0	.010328	.000411	.001972	.006929
39.0	.014095	.000456	.002172	.007576
40.0	.018691	.000501	.002374	.008223
41.0	.024143	.000545	.002575	.008862
42.0	.030451	.000591	.002772	.009487

BLOCKING PROBABILITIES FOR C = 50   A = 7

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
32.0	.000754	.000008	.000062	.000321
33.0	.001294	.000010	.000074	.000380
34.0	.002121	.000012	.000087	.000446
35.0	.003333	.000014	.000102	.000518
36.0	.005036	.000017	.000118	.000595
37.0	.007335	.000019	.000136	.000678
38.0	.010328	.000022	.000154	.000765
39.0	.014095	.000025	.000173	.000855
40.0	.018691	.000028	.000193	.000947
41.0	.024143	.000031	.000213	.001040
42.0	.030451	.000034	.000232	.001131

BLOCKING PROBABILITIES FOR C = 50   A = 8

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
32.0	.000754	.000000	.000003	.000021
33.0	.001294	.000000	.000004	.000026
34.0	.002121	.000000	.000004	.000032
35.0	.003333	.000001	.000005	.000038
36.0	.005036	.000001	.000006	.000045
37.0	.007335	.000001	.000007	.000052
38.0	.010328	.000001	.000009	.000060
39.0	.014095	.000001	.000010	.000068
40.0	.018691	.000001	.000011	.000077
41.0	.024143	.000001	.000013	.000086
42.0	.030451	.000001	.000014	.000095

BLOCKING PROBABILITIES FOR C = 50   A = 9

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
32.0	.000754	.000000	000000	.000001
33.0	.001294	.000000	000000	.000001
34.0	.002121	.000000	.000000	000002
35.0	.003333	.000000	.000000	.000002
36.0	005036	.000000	.000000	.000003
37.0	.007335	.000000	.000000	.000003
38.0	.010328	.000000	000000	.000004
39.0	.014095	.000000	.000000	.000004
40.0	.018691	.000000	.000000	.000005
41.0	.024143	.000000	.000001	.000005
42.0	.030451	.000000	.000001	.000006

BLOCKING PROBABILITIES FOR C = 50   A = 10

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
32.0	.000754	.000000	.000000	.000000
33.0	.001294	.000000	.000000	.000000
34.0	.002121	.000000	.000000	.000000
35.0	.003333	.000000	.000000	.000000
36.0	.005036	.000000	.000000	.000000
37.0	.007335	.000000	.000000	.000000
38.0	.010328	.000000	.000000	.000000
39.0	.014095	.000000	.000000	.000000
40.0	.018691	.000000	.000000	.000000
41.0	.024143	.000000	000000	.000000
42.0	.030451	.000000	.000000	.000000

BLOCKING PROBABILITIES FOR C = 60   A = 5

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
40.0	.000679	.006764	.021187	.050580
41.0	.001101	.007406	.022966	.054240
42.0	.001722	.008078	.024804	.057970
43.0	.002604	.008776	.026690	.061750
44.0	.003818	.009495	.028613	.065554
45.0	.005434	.010230	.030556	.069356
46.0	.007522	.010974	.032505	.073128
47.0	.010146	.011721	.034443	.076841
48.0	.013356	.012465	.036355	.080467
49.0	.017190	.013198	.038225	.083983
50.0	.021668	.013915	.040039	.087366
51.0	.026794	.014610	.041787	.090599
52.0	.032554	.015280	.043458	.093668
53.0	.038919	.015920	.045046	.096565
54.0	.045849	.016529	.046547	.099287
55.0	.053294	.017104	.047959	.101831

BLOCKING PROBABILITIES FOR C = 60   A = 6

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
40.0	.000679	.000579	.002693	.009147
41.0	.001101	.000652	.003005	.010103
42.0	.001722	.000730	.003337	.011109
43.0	.002604	.000814	.003687	.012158
44.0	.003818	.000902	.004054	.013244
45.0	.005434	.000994	.004433	.014357
46.0	.007522	.001089	.004823	.015490
47.0	.010146	.001187	.005219	.016630
48.0	.013356	.001285	.005618	.017767

49.0	.017190	.001384	.006015	.018891
50.0	.021668	.001483	.006406	.019992
51.0	.026794	.001579	.006790	.021062
52.0	.032554	.001674	.007161	.022094
53.0	.038919	.001765	.007520	.023082
54.0	.045849	.001853	.007863	.024023
55.0	.053294	.001937	.008189	.024913

BLOCKING PROBABILITIES FOR C = 60 A = 7

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
40.0	.000679	.000034	.000232	.001115
41.0	.001101	.000039	.000266	.001267
42.0	.001722	.000045	.000303	.001432
43.0	.002604	.000052	.000343	.001609
44.0	.003818	.000058	.000386	.001797
45.0	.005434	.000066	.000432	.001996
46.0	.007522	.000073	.000480	.002199
47.0	.010146	.000081	.000529	.002409
48.0	.013356	.000090	.000580	.002623
49.0	.017190	.000098	.000631	.002838
50.0	.021668	.000106	.000682	.003052
51.0	.026794	.000115	.000733	.003264
52.0	.032554	.000123	.000783	.003470
53.0	.038919	.000131	.000832	.003671
54.0	.045849	.000139	.000879	.003864
55.0	.053294	.000147	.000924	.004049

BLOCKING PROBABILITIES FOR C = 60 A = 8

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
40.0	.000679	.000001	.000014	.000097
41.0	.001101	.000002	.000017	.000113
42.0	.001722	.000002	.000020	.000131
43.0	.002604	.000002	.000023	.000151
44.0	.003818	.000003	.000026	.000173
45.0	.005434	.000003	.000030	.000196
46.0	.007522	.000004	.000034	.000220
47.0	.010146	.000004	.000038	.000246
48.0	.013356	.000005	.000043	.000272
49.0	.017190	.000005	.000047	.000299
50.0	.021668	.000005	.000052	.000327
51.0	.026794	.000006	.000056	.000354
52.0	.032554	.000006	.000061	.000381
53.0	.038919	.000007	.000065	.000407
54.0	.045849	.000007	.000069	.000433
55.0	.053294	.000008	.000073	.000458

BLOCKING PROBABILITIES FOR C = 60 A = 9

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
40.0	.000679	.000000	.000001	.000006
41.0	.001101	.000000	.000001	.000008
42.0	.001722	.000000	.000001	.000009
43.0	.002604	.000000	.000001	.000011
44.0	.003818	.000000	.000001	.000012
45.0	.005434	.000000	.000002	.000014
46.0	.007522	.000000	.000002	.000016
47.0	.010146	.000000	.000002	.000019
48.0	.013356	.000000	.000002	.000021
49.0	.017190	.000000	.000003	.000023
50.0	.021668	.000000	.000003	.000026
51.0	.026794	.000000	.000003	.000028
52.0	.032554	.000000	.000003	.000031
53.0	.038919	.000000	.000004	.000033
54.0	.045849	.000000	.000004	.000036
55.0	.053294	.000000	.000004	.000038

BLOCKING PROBABILITIES FOR C = 60 A = 10

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
40.0	.000679	.000000	.000000	000000
41.0	.001101	.000.00	.000000	.000000
42.0	.001722	.000000	.000000	.000000
43.0	.002604	.000000	.000000	.000001
44.0	.003818	.000000	.000000	.000001
45.0	.005434	.000000	.000000	.000001
46.0	.007522	.000000	.000000	.000001
47.0	.010146	.000000	.000000	.000001
48.0	.013356	.000000	.000000	.000001
49.0	017190	.000000	.000000	.000001
50.0	.021668	.000000	.000000	.000002
51.0	.026794	.000000	.000000	.000002
52.0	.032554	.000000	.000000	.000002
53.0	.038919	.000000	.000000	.000002
54.0	.045849	.000000	.000000	.000002
55.0	.053294	.000000	.000000	.000002

BLOCKING PROBABILITIES FOR C = 60 A = 11

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
40.0	.000679	.000000	.000000	.000000
41.0	.001101	.000000	.000000	.000000
42.0	.001722	.000000	.000000	.000000
43.0	.002604	.000000	.000000	.000000
44.0	.003818	.000000	.000000	.000000
45.0	.005434	.000000	.000000	.000000
46.0	.007522	.000000	.000000	.000000
47.0	.010146	.000000	.000000	.000000
48.0	.013356	.000000	.000000	.000000
49.0	.017190	.000000	.000000	.000000
50.0	.021668	.000000	.000000	.000000
51.0	.026794	.000000	.000000	.000000
52.0	.032554	.000000	.000000	.000000
53.0	.038919	.000000	.000000	.000000
54.0	.045849	.000000	.000000	.000000
55.0	.053294	.000000	.000000	.000000

BLOCKING PROBABILITIES FOR C = 70 A = 5

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
50.0	.001368	.015217	.043014	.092368
51.0	.002016	.016257	.045527	.096856
52.0	.002895	.017318	.048067	.101339
53.0	.004054	.018397	.050619	.105795
54.0	.005545	.019485	.053168	.110199
55.0	.007417	.020575	.055699	.114528
56.0	.009714	.021660	.058194	.118757
57.0	.012474	.022733	.060639	.122865
58.0	.015723	.023785	.063019	.126831
59.0	.019478	.024811	.065321	.130639
60.0	.023744	.025805	.067536	.134274
61.0	.028517	.026761	.069654	.137728
62.0	.033779	.027677	.071669	.140994
63.0	.039506	.028550	.073578	.144068
64.0	.045668	.029378	.075379	.146953
65.0	.052227	.030160	.077072	.149651

BLOCKING PROBABILITIES FOR C = 70 A = 6

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)

50.0	.001368	.001703	.007205	.022015
51.0	.002016	.001860	.007805	.023619
52.0	.002895	.002024	.008425	.025262
53.0	.004054	.002194	.009062	.026931
54.0	.005545	.002370	.009712	.028617
55.0	.007417	.002549	.010370	.030309
56.0	.009714	.002730	.011031	.031992
57.0	.012474	.002911	.011690	.033657
58.0	.015723	.003093	.012342	.035291
59.0	.019478	.003272	.012982	.036584
60.0	.023744	.003447	.013607	.038428
61.0	.028517	.003619	.014213	.039913
62.0	.033779	.003784	.014796	.041336
63.0	.039506	.003944	.015355	.042691
64.0	.045668	.004097	.015988	.043977
65.0	.052227	.004243	.016394	.045192

BLOCKING PROBABILITIES FOR C = 70 A = 7

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
50.0	.001368	.000129	.000811	.003543
51.0	.002016	.000144	.000898	.003890
52.0	.002895	.000160	.000990	.004253
53.0	.004054	.000177	.001087	.004631
54.0	.005545	.000194	.001187	.005020
55.0	.007417	.000213	.001290	.005418
56.0	.009714	.000231	.001396	.005821
57.0	.012474	.000250	.001503	.006227
58.0	.015723	.000270	.001610	.006631
59.0	.019478	.000289	.001717	.007031
60.0	.023744	.000308	.001822	.007424
61.0	.028517	.000327	.001926	.007807
62.0	.033779	.000345	.002026	.008179
63.0	.039506	.000363	.002124	.008536
64.0	.045668	.000380	.002218	.008879
65.0	.052227	.000397	.002307	.009206

BLOCKING PROBABILITIES FOR C = 70 A = 8

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
50.0	.001368	.000007	.000065	.000404
51.0	.002016	.000008	.000074	.000453
52.0	.002895	.000009	.000083	.0005[illegible]5
53.0	.004054	.000010	.000093	.000561
54.0	.005545	.000011	.000103	.000620
55.0	.007417	.000013	.000114	.000681
56.0	.009714	.000014	.000125	.000743
57.0	.012474	.000015	.000137	.000807
58.0	.015723	.000017	.000148	.000872
59.0	.019478	.000018	.000160	.000937
60.0	.023744	.000020	.000172	.001001
61.0	.028517	.000021	.000183	.001065
62.0	.033779	.000022	.000195	.001127
63.0	.039506	.000024	.000206	.001188
64.0	.045668	.000025	.000217	.001246
65.0	.052227	.000026	.000227	.001302

BLOCKING PROBABILITIES FOR C = 70 A = 9

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
50.0	.001368	.000000	.000004	.000034
51.0	.002016	.000000	.000005	.000039
52.0	.002895	.000000	.000005	.000045
53.0	.004054	.000000	.000006	.000050
54.0	.005545	.000001	.000007	.000057
55.0	.007417	.000001	.000007	.000063
56.0	.009714	.000001	.000008	.000070
57.0	.012474	.000001	.000009	.000077
58.0	.015723	.000001	.000010	.000084
59.0	.019478	.000001	.000011	.000092
60.0	.023744	.000001	.000012	.000099
61.0	.028517	.000001	.000013	.000106
62.0	.033779	.000001	.000014	.000113
63.0	.039506	.000001	.000015	.000121
64.0	.045668	.000001	.000016	.000127
65.0	.052227	.000001	.000017	.000134

BLOCKING PROBABILITIES FOR C = 70 A = 10

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
50.0	.001368	.000000	.000000	.000002
51.0	.002016	.000000	.000000	.000003
52.0	.002895	.000000	.000000	.000003
53.0	.004054	.000000	.000000	.000003
54.0	.005545	.000000	.000000	.000004
55.0	.007417	.000000	.000000	.000004
56.0	.009714	.000000	.000000	.000005
57.0	.012474	.000000	.000000	.000006
58.0	.015723	.000000	.000001	.000006
59.0	.019478	.000000	.000001	.000007
60.0	.023744	.000000	.000001	.000007
61.0	.028517	.000000	.000001	.000008
62.0	.033779	.000000	.000001	.000009
63.0	.039506	.000000	.000001	.000009
64.0	.045668	.000000	.000001	.000010
65.0	.052227	.000000	.000001	.000010

BLOCKING PROBABILITIES FOR C = 70 A = 11

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
50.0	.001368	.000000	.000000	.000000
51.0	.002016	.000000	.000000	.000000
52.0	.002895	.000000	.000000	.000000
53.0	.004054	.000000	.000000	.000000
54.0	.005545	.000000	.000000	.000000
55.0	.007417	.000000	.000000	.000000
56.0	.009714	.000000	.000000	.000000
57.0	.012474	.000000	.000000	.000000
58.0	.015723	.000000	.000000	.000000
59.0	.019478	.000000	.000000	.000000
60.0	.023744	.000000	.000000	.000000
61.0	.028517	.000000	.000000	.000000
62.0	.033779	.000000	.000000	.000001
63.0	.039506	.000000	.000000	.000001
64.0	.045668	.000000	.000000	.000001
65.0	.052227	.000000	.000000	.000001

BLOCKING PROBABILITIES FOR C = 80 A = 6

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
60.0	.002199	.003922	.015139	.041935
61.0	.003043	.004199	.016081	.044050
62.0	.004126	.004483	.017036	.046275
63.0	.005485	.004773	.018001	.048501
64.0	.007158	.005066	.018970	.050713
65.0	.009176	.005360	.019935	.052901
66.0	.011570	.005654	.020892	.055051
67.0	.014358	.005945	.021835	.057153
68.0	.017557	.006232	.022758	.059196
69.0	.021172	.006514	.023657	.061171
70.0	.025203	.006788	.024528	.063072

71.0	.029640	.007053	.025367	.064893
72.0	.034468	.007310	.026171	.066629
73.0	.039668	.007555	.026940	.068278
74.0	.045214	.007790	.027672	.069840
75.0	.051078	.008015	.028366	.071315

BLOCKING PROBABILITIES FOR C = 80 A = 7

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
60.0	.002199	.000369	.002135	.008483
61.0	.003043	.000402	.002310	.009103
62.0	.004126	.000437	.002491	.009738
63.0	.005485	.000472	.002677	.010385
64.0	.007158	.000509	.002866	.011039
65.0	.009176	.000546	.003057	.011697
66.0	.011570	.000584	.003250	.012352
67.0	.014358	.000622	.003442	.013003
68.0	.017557	.000659	.003633	.013643
69.0	.021172	.000696	.003820	.014271
70.0	.025203	.000733	.004004	.014882
71.0	.029640	.000769	.004183	.015473
72.0	.034468	.000804	.004356	.016043
73.0	.039668	.000837	.004523	.016590
74.0	.045214	.000870	.004684	.017112
75.0	.051078	.000901	.004837	.017610

BLOCKING PROBABILITIES FOR C = 80 A = 8

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
60.0	.002199	.000025	.000213	.001212
61.0	.003043	.000028	.000235	.001324
62.0	.004126	.000031	.000257	.001441
63.0	.005485	.000033	.000281	.001563
64.0	.007158	.000037	.000305	.001687
65.0	.009176	.000040	.000330	.001814
66.0	.011570	.000043	.000356	.001943
67.0	.014358	.000046	.000381	.002072
68.0	.017557	.000050	.000407	.002201
69.0	.021172	.000053	.000432	.002328
70.0	.025203	.000056	.000458	.002453
71.0	.029640	.000059	.000482	.002576
72.0	.034468	.000063	.000506	.002695
73.0	.039668	.000066	.000530	.002811
74.0	.045214	.000069	.000553	.002922
75.0	.051078	.000072	.000575	.003028

BLOCKING PROBABILITIES FOR C = 80 A = 9

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
60.0	.002199	.000001	.000016	.000128
61.0	.003043	.000001	.000018	.000142
62.0	.004126	.000002	.000020	.000157
63.0	.005485	.000002	.000022	.000173
64.0	.007158	.000002	.000024	.000189
65.0	.009176	.000002	.000026	.000206
66.0	.011570	.000002	.000029	.000224
67.0	.014358	.000003	.000031	.000241
68.0	.017557	.000003	.000034	.000259
69.0	.021172	.000003	.000036	.000277
70.0	.025203	.000003	.000039	.000294
71.0	.029640	.000003	.000041	.000312
72.0	.034468	.000004	.000043	.000329
73.0	.039668	.000004	.000046	.000346
74.0	.045214	.000004	.000048	.000362
75.0	.051078	.000004	.000050	.000377

BLOCKING PROBABILITIES FOR C = 80 A = 10

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
60.0	.002199	.000000	.000001	.000010
61.0	.003043	.000000	.000001	.000012
62.0	.004126	.000000	.000001	.000013
63.0	.005485	.000000	.000001	.000015
64.0	.007158	.000000	.000001	.000016
65.0	.009176	.000000	.000002	.000018
66.0	.011570	.000000	.000002	.000020
67.0	.014358	.000000	.000002	.000021
68.0	.017557	.000000	.000002	.000023
69.0	.021172	.000000	.000002	.000025
70.0	.025203	.000000	.000002	.000027
71.0	.029640	.000000	.000003	.000029
72.0	.034468	.000000	.000003	.000030
73.0	.039668	.000000	.000003	.000032
74.0	.045214	.000000	.000003	.000034
75.0	.051078	.000000	.000003	.000036

BLOCKING PROBABILITIES FOR C = 80 A = 11

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
60.0	.002199	.000000	.000000	.000001
61.0	.003043	.000000	.000000	.000001
62.0	.004126	.000000	.000000	.000001
63.0	.005485	.000000	.000000	.000001
64.0	.007158	.000000	.000000	.000001
65.0	.009176	.000000	.000000	.000001
66.0	.011570	.000000	.000000	.000001
67.0	.014358	.000000	.000000	.000001
68.0	.017557	.000000	.000000	.000002
69.0	.021172	.000000	.000000	.000002
70.0	.025203	.000000	.000000	.000002
71.0	.029640	.000000	.000000	.000002
72.0	.034468	.000000	.000000	.000002
73.0	.039668	.000000	.000000	.000002
74.0	.045214	.000000	.000000	.000002
75.0	.051078	.000000	.000000	.000003

BLOCKING PROBABILITIES FOR C = 80 A = 12

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
60.0	.002199	.000000	.000000	.000000
61.0	.003043	.000000	.000000	.000000
62.0	.004126	.000000	.000000	.000000
63.0	.005485	.000000	.000000	.000000
64.0	.007158	.000000	.000000	.000000
65.0	.009176	.000000	.000000	.000000
66.0	.011570	.000000	.000000	.000000
67.0	.014358	.000000	.000000	.000000
68.0	.017557	.000000	.000000	.000000
69.0	.021172	.000000	.000000	.000000
70.0	.025203	.000000	.000000	.000000
71.0	.029640	.000000	.000000	.000000
72.0	.034468	.000000	.000000	.000000
73.0	.039668	.000000	.000000	.000000
74.0	.045214	.000000	.000000	.000000
75.0	.051078	.000000	.000000	.000000

BLOCKING PROBABILITIES FOR C = 90 A = 6

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
70.0	.003092	.007640	.024982	.067914

71.0	.004092	.008066	.028273	.070600
72.0	.005325	.008497	.029566	.073268
73.0	.006820	.008930	.030855	.075906
74.0	.008603	.009363	.032135	.078502
75.0	.010695	.009796	.033398	.081044
76.0	.013115	.010220	.034639	.083522
77.0	.015874	.010639	.035851	.085927
78.0	.018980	.011049	.037030	.088251
79.0	.022434	.011448	.038172	.090487
80.0	.026232	.011835	.039273	.092629
81.0	.030365	.012209	.040330	.094675
82.0	.034819	.012569	.041342	.096623
83.0	.039577	.012913	.042307	.098470
84.0	.044620	.013242	.043224	.100219
85.0	.049926	.013556	.044094	.101871

BLOCKING PROBABILITIES FOR C = 90 A = 7

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
70.0	.003092	.000867	.004622	.016741
71.0	.004092	.000929	.004920	.017681
72.0	.005325	.000993	.005223	.018629
73.0	.006820	.001058	.005529	.019581
74.0	.008603	.001124	.005837	.020532
75.0	.010695	.001190	.006146	.021475
76.0	.013115	.001256	.006452	.022407
77.0	.015874	.001321	.006755	.023322
78.0	.018980	.001386	.007053	.024216
79.0	.022434	.001450	.007344	.025085
80.0	.026232	.001512	.007628	.025927
81.0	.030365	.001573	.007903	.026739
82.0	.034819	.001632	.008168	.027518
83.0	.039577	.001689	.008423	.028264
84.0	.044620	.001743	.008668	.028976
85.0	.049926	.001796	.008902	.029653

BLOCKING PROBABILITIES FOR C = 90 A = 8

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
70.0	.003092	.000070	.000558	.002909
71.0	.004092	.000076	.000603	.003121
72.0	.005325	.000083	.000649	.003338
73.0	.006820	.000089	.000696	.003558
74.0	.008603	.000096	.000744	.003782
75.0	.010695	.000102	.000793	.004006
76.0	.013115	.000109	.000842	.004230
77.0	.015874	.000116	.000890	.004453
78.0	.018980	.000123	.000939	.004673
79.0	.022434	.000130	.000987	.004890
80.0	.026232	.000136	.001034	.005101
81.0	.030365	.000143	.001080	.005306
82.0	.034819	.000149	.001124	.005505
83.0	.039577	.000155	.001168	.005697
84.0	.044620	.000161	.001209	.005882
85.0	.049926	.000167	.001250	.006059

BLOCKING PROBABILITIES FOR C = 90 A = 9

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
70.0	.003092	.000004	.000050	.000370
71.0	.004092	.000005	.000055	.000403
72.0	.005325	.000005	.000060	.000437
73.0	.006820	.000006	.000065	.000472
74.0	.008603	.000006	.000070	.000508
75.0	.010695	.000007	.000075	.000545
76.0	.013115	.000007	.000081	.000582
77.0	.015874	.000008	.000086	.000618
78.0	.018980	.000008	.000092	.000655
79.0	.022434	.000009	.000097	.000692
80.0	.026232	.000009	.000103	.000728
81.0	.030365	.000010	.000108	.000763
82.0	.034819	.000010	.000113	.000798
83.0	.039577	.000011	.000118	.000831
84.0	.044620	.000011	.000123	.000863
85.0	.049926	.000012	.000128	.000895

BLOCKING PROBABILITIES FOR C = 90 A = 10

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
70.0	.003092	.000000	.000003	.000036
71.0	.004092	.000000	.000004	.000040
72.0	.005325	.000000	.000004	.000044
73.0	.006820	.000000	.000005	.000048
74.0	.008603	.000000	.000005	.000052
75.0	.010695	.000000	.000005	.000056
76.0	.013115	.000000	.000006	.000061
77.0	.015874	.000000	.000006	.000065
78.0	.018980	.000000	.000007	.000070
79.0	.022434	.000000	.000007	.000074
80.0	.026232	.000000	.000008	.000078
81.0	.030365	.000001	.000008	.000083
82.0	.034819	.000001	.000009	.000087
83.0	.039577	.000001	.000009	.000091
84.0	.044620	.000001	.000010	.000095
85.0	.049926	.000001	.000010	.000099

BLOCKING PROBABILITIES FOR C = 90 A = 11

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
70.0	.003092	.000000	.000000	.000003
71.0	.004092	.000000	.000000	.000003
72.0	.005325	.000000	.000000	.000003
73.0	.006820	.000000	.000000	.000004
74.0	.008603	.000000	.000000	.000004
75.0	.010695	.000000	.000000	.000005
76.0	.013115	.000000	.000000	.000005
77.0	.015874	.000000	.000000	.000005
78.0	.018980	.000000	.000000	.000006
79.0	.022434	.000000	.000000	.000006
80.0	.026232	.000000	.000000	.000007
81.0	.030365	.000000	.000000	.000007
82.0	.034819	.000000	.000001	.000007
83.0	.039577	.000000	.000001	.000008
84.0	.044620	.000000	.000001	.000008
85.0	.049926	.000000	.000001	.000009

BLOCKING PROBABILITIES FOR C = 90 A = 12

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
70.0	.003092	.000000	.000000	.000000
71.0	.004092	.000000	.000000	.000000
72.0	.005325	.000000	.000000	.000000
73.0	.006820	.000000	.000000	.000000
74.0	.008603	.000000	.000000	.000000
75.0	.010695	.000000	.000000	.000000
76.0	.013115	.000000	.000000	.000000
77.0	.015874	.000000	.000000	.000000
78.0	.018980	.000000	.000000	.000000
79.0	.022434	.000000	.000000	.000000
80.0	.026232	.000000	.000000	000000
81.0	.030365	.000000	.000000	.000000
82.0	.034819	.000000	.000000	.000001

83.0	.039577	.000000	.000000	.000001
84.0	.044620	.000000	.000000	.000001
85.0	.049926	.000000	.000000	.000001

BLOCKING PROBABILITIES FOR C = 100 A = 7

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
80.0	.003992	.001745	.008680	.028751
81.0	.005109	.001849	.009129	.030016
82.0	.006449	.001973	.009580	.031279
83.0	.008030	.002079	.010032	.032534
84.0	.009873	.002185	.010482	.033775
85.0	.011990	.002290	.010929	.034997
86.0	.014395	.002395	.011369	.036195
87.0	.017093	.002498	.011802	.037364
88.0	.020088	.002600	.012224	.038500
89.0	.023378	.002699	.012636	.039600
90.0	.026957	.002796	.013035	.040661
91.0	.030818	.002890	.013421	.041681
92.0	.034948	.002981	.013792	.042658
93.0	.039334	.003068	.014149	.043592
94.0	.043958	.003152	.014490	.044482
95.0	.048804	.003233	.014816	.045328

BLOCKING PROBABILITIES FOR C = 100 A = 8

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
80.0	.003992	.000167	.001238	.005937
81.0	.005109	.000179	.001319	.006283
82.0	.006449	.000192	.001401	.006632
83.0	.008030	.000204	.001484	.006984
84.0	.009873	.000217	.001568	.007336
85.0	.011990	.000229	.001653	.007687
86.0	.014395	.000242	.001736	.008034
87.0	.017093	.000255	.001819	.008376
88.0	.020088	.000267	.001901	.008712
89.0	.023378	.000280	.001982	.009040
90.0	.026957	.000292	.002060	.009359
91.0	.030818	.000303	.002137	.009668
92.0	.034948	.000315	.002211	.009967
93.0	.039334	.000326	.002282	.010254
94.0	.043958	.000337	.002351	.010530
95.0	.048804	.000347	.002418	.010794

BLOCKING PROBABILITIES FOR C = 100 A = 9

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
80.0	.003992	.000012	.000130	.000895
81.0	.005109	.000013	.000140	.000959
82.0	.006449	.000014	.000151	.001025
83.0	.008030	.000015	.000161	.001092
84.0	.009873	.000016	.000172	.001159
85.0	.011990	.000017	.000183	.001228
86.0	.014395	.000018	.000194	.001296
87.0	.017093	.000019	.000205	.001363
88.0	.020088	.000020	.000216	.001430
89.0	.023378	.000021	.000227	.001496
90.0	.026957	.000023	.000237	.001561
91.0	.030818	.000024	.000248	.001624
92.0	.034948	.000025	.000258	.001685
93.0	.039334	.000026	.000268	.001745
94.0	.043958	.000027	.000277	.001802
95.0	.048804	.000028	.000287	.001857

BLOCKING PROBABILITIES FOR C = 100 A = 10

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
80.0	.003992	.000001	.000010	.000102
81.0	.005109	.000001	.000011	.000111
82.0	.006449	.000001	.000012	.000120
83.0	.008030	.000001	.000013	.000129
84.0	.009873	.000001	.000014	.000138
85.0	.011990	.000001	.000015	.000148
86.0	.014395	.000001	.000017	.000158
87.0	.017093	.000001	.000018	.000167
88.0	.020088	.000001	.000019	.000177
89.0	.023378	.000001	.000020	.000186
90.0	.026957	.000001	.000021	.000196
91.0	.030818	.000001	.000022	.000205
92.0	.034948	.000001	.000023	.000214
93.0	.039334	.000002	.000024	.000223
94.0	.043958	.000002	.000025	.000231
95.0	.048804	.000002	.000026	.000239

BLOCKING PROBABILITIES FOR C = 100 A = 11

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
80.0	.003992	.000000	.000001	.000009
81.0	.005109	.000000	.000001	.000010
82.0	.006449	.000000	.000001	.000011
83.0	.008030	.000000	.000001	.000012
84.0	.009873	.000000	.000001	.000013
85.0	.011990	.000000	.000001	.000014
86.0	.014395	.000000	.000001	.000015
87.0	.017093	.000000	.000001	.000016
88.0	.020088	.000000	.000001	.000017
89.0	.023378	.000000	.000001	.000018
90.0	.026957	.000000	.000001	.000019
91.0	.030818	.000000	.000002	.000020
92.0	.034948	.000000	.000002	.000021
93.0	.039334	.000000	.000002	.000022
94.0	.043958	.000000	.000002	.000023
95.0	.048804	.000000	.000002	.000024

BLOCKING PROBABILITIES FOR C = 100 A = 12

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
80.0	.003992	.000000	.000000	.000001
81.0	.005109	.000000	.000000	.000001
82.0	.006449	.000000	.000000	.000001
83.0	.008030	.000000	.000000	.000001
84.0	.009873	.000000	.000000	.000001
85.0	.011990	.000000	.000000	.000001
86.0	.014395	.000000	.000000	.000001
87.0	.017093	.000000	.000000	.000001
88.0	.020088	.000000	.000000	.000001
89.0	.023378	.000000	.000000	.000001
90.0	.026957	.000000	.000000	.000001
91.0	.030818	.000000	.000000	.000002
92.0	.034948	.000000	.000000	.000002
93.0	.039334	.000000	.000000	.000002
94.0	.043958	.000000	.000000	.000002
95.0	.048804	.000000	.000000	.000002

BLOCKING PROBABILITIES FOR C = 100 A = 13

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
80.0	.003992	.000000	.000000	.000000
81.0	.005109	.000000	.000000	.000000
82.0	.006449	.000000	.000000	.000000

83.0	.008030	000000	.000000	.000000
84.0	.009873	.000000	.000000	.000000
85.0	.011990	.000000	.000000	.000000
86.0	.014395	.000000	.000000	.000000
87.0	.017093	.000000	.000000	.000000
88.0	.020088	.000000	.000000	.000000
89.0	.023378	.000000	.000000	.000000
90.0	.026957	.000000	.000000	.000000
91.0	.030818	.000000	.000000	.000000
92.0	034948	.000000	.000000	.000000
93.0	.039334	.000000	.000000	.000000
94.0	.043958	.000000	.000000	.000000
95.0	048804	.000000	.000000	.000000

BLOCKING PROBABILITIES FOR C = 125   A = 7

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
100.0	.001989	.005526	.023114	.064527
101.0	.002544	.005776	.023994	.066509
102.0	.003217	.006029	.024879	.068486
103.0	.004021	.006285	.025766	.070452
104.0	.004971	.006542	.026652	.072401
105.0	.006082	.006800	.027534	.074328
106.0	007366	.007057	.028410	.076226
107.0	.008835	.007314	.029276	.078091
108.0	.010498	.007568	.030129	.079917
109.0	.012363	.007819	.030966	.081699
110.0	.014434	.008066	.031786	.083433
111.0	.016717	.008308	.032586	.085115
112.0	.019210	.008545	.033365	.086742
113.0	.021913	.008775	.034119	.088312
114.0	.024823	.008999	.034849	.089823
115.0	.027934	.009217	.035553	.091274

BLOCKING PROBABILITIES FOR C = 125   A = 8

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
100.0	.001989	.000696	.004431	.017927
101.0	.002544	.000736	.004653	.018693
102.0	.003217	.000776	.004879	.019465
103.0	.004021	.000817	.005108	.020243
104.0	.004971	.000859	.005339	.021022
105.0	.006082	.000902	.005572	.021801
106.0	.007366	.000944	.005805	.022575
107.0	.008835	.000987	.006038	.023344
108.0	.010498	.001030	.006269	.024103
109.0	.012363	.001072	.006498	.024850
110.0	.014434	.001115	006724	.025584
111.0	.016717	.001156	.006946	.026301
112.0	.019210	.001197	.007164	.027000
113.0	.021913	.001238	.007377	.027679
114.0	.024823	.001277	.007584	.028337
115.0	.027934	.001315	.007784	.028973

BLOCKING PROBABILITIES FOR C = 125   A = 9

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
100.0	.001989	.000065	.000620	.003647
101.0	.002544	.000069	.000659	.003848
102.0	.003217	.000074	.000698	.004052
103.0	.004021	.000078	.000739	.004260
104.0	.004971	.000083	.000780	.004471
105.0	.006082	.000088	.000821	.004683
106.0	.007366	.000093	.000864	.004897
107.0	.008835	.000098	.000906	.005110
108.0	.010498	.000103	.000949	.005324
109.0	.012363	.000108	.000991	.005535
110.0	.014434	.000113	.001033	.005744
111.0	.016717	.000118	.001075	.005950
112.0	.019210	.000123	.001116	.006153
113.0	.021913	.000128	.001157	.006351
114.0	.024823	.000133	.001196	.006544
115.0	.027934	.000137	.001235	.006732

BLOCKING PROBABILITIES FOR C = 125   A = 10

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
100.0	.001989	.000005	.000066	.000559
101.0	.002544	.000005	.000071	.000596
102.0	.003217	.000005	.000076	.000635
103.0	.004021	.000006	.000081	.000674
104.0	.004971	.000006	.000086	.000714
105.0	.006082	.000007	.000092	.000756
106.0	.007366	.000007	.000097	.000797
107.0	.008835	.000007	.000103	.000839
108.0	.010498	.000008	.000109	.000881
109.0	.012363	.000008	.000114	.000924
110.0	.014434	.000009	.000120	.000966
111.0	.016717	.000009	.000126	.001008
112.0	.019210	.000010	.000131	.001049
113.0	.021913	.000010	.000137	.001089
114.0	.024823	.000011	.000142	.001129
115.0	.027934	.000011	.000148	.001168

BLOCKING PROBABILITIES FOR C = 125   A = 11

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
100.0	.001989	.000000	.000006	.000067
101.0	.002544	.000000	.000006	.000072
102.0	.003217	.000000	.000006	.000077
103.0	.004021	.000000	.000007	.000083
104.0	.004971	.000000	.000008	.000089
105.0	.006082	.000000	.000008	.000095
106.0	.007366	.000000	.000009	.000101
107.0	.008835	.000000	.000009	.000107
108.0	.010498	.000000	.000010	.000113
109.0	.012363	.000001	.000010	.000119
110.0	.014434	.000001	.000011	.000126
111.0	.016717	.000001	.000011	.000132
112.0	.019210	.000001	.000012	.000138
113.0	.021913	.000001	.000013	.000144
114.0	.024823	.000001	.000013	.000150
115.0	.027934	.000001	.000014	.000156

BLOCKING PROBABILITIES FOR C = 125   A = 12

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
100.0	.001989	.000000	.000000	.000006
101.0	.002544	.000000	.000000	.000007
102.0	.003217	.000000	.000000	.000008
103.0	.004021	.000000	.000000	.000008
104.0	.004971	.000000	.000001	.000009
105.0	.006082	.000000	.000001	.000009
106.0	.007366	.000000	.000001	.000010
107.0	.008835	.000000	.000001	.000011
108.0	.010498	.000000	.000001	.000012
109.0	.012363	.000000	.000001	.000012
110.0	.014434	.000000	.000001	.000013
111.0	.016717	.000000	.000001	.000014
112.0	.019210	.000000	.000001	.000014
113.0	.021913	.000000	.000001	.000015
114.0	.024823	.000000	.000001	.000016

115.0	.027934	.000000	.000001	.000017

BLOCKING PROBABILITIES FOR C = 125 A = 13

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
100.0	.001989	.000000	.000000	.000001
101.0	.002544	.000000	.000000	.000001
102.0	.003217	.000000	.000000	.000001
103.0	.004021	.000000	.000000	.000001
104.0	.004971	.000000	.000000	.000001
105.0	.006092	.000000	.000000	.000001
106.0	.007366	.000000	.000000	.000001
107.0	.008825	.000000	.000000	.000001
108.0	.010498	.000000	.000000	.000001
109.0	.012363	.000000	.000000	.000001
110.0	.014434	.000000	.000000	.000001
111.0	.016717	.000000	.000000	.000001
112.0	.019210	.000000	.000000	.000001
113.0	.021913	.000000	.000000	.000001
114.0	.024823	.000000	.000000	.000001
115.0	.027934	.000000	.000000	.000001

BLOCKING PROBABILITIES FOR C = 150 A = 8

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
125.0	.003152	.002545	.013575	.045304
126.0	.003844	.002647	.014038	.046555
127.0	.004649	.002750	.014501	.047798
128.0	.005574	.002854	.014964	.049032
129.0	.006630	.002957	.015425	.050252
130.0	.007823	.003061	.015882	.051457
131.0	.009162	.003164	.016335	.052642
132.0	.010651	.003266	.016782	.053805
133.0	.012295	.003367	.017222	.054944
134.0	.014097	.003466	.017654	.056056
135.0	.016059	.003564	.018077	.057138

BLOCKING PROBABILITIES FOR C = 150 A = 9

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
125.0	.003152	.000312	.002537	.012372
126.0	.003844	.000327	.002646	.012829
127.0	.004649	.000342	.002757	.013287
128.0	.005574	.000358	.002868	.013745
129.0	.006630	.000374	.002980	.014203
130.0	.007823	.000389	.003092	.014657
131.0	.009162	.000405	.003204	.015109
132.0	.010651	.000421	.003315	.015555
133.0	.012295	.000437	.003425	.015994
134.0	.014097	.000452	.003533	.016426
135.0	.016059	.000468	.003640	.016850

BLOCKING PROBABILITIES FOR C = 150 A = 10

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
125.0	.003152	.000029	.000357	.002541
126.0	.003844	.000031	.000376	.002658
127.0	.004649	.000032	.000395	.002776
128.0	.005574	.000034	.000414	.002896
129.0	.006630	.000036	.000433	.003016
130.0	.007823	.000038	.000452	.003137
131.0	.009162	.000039	.000472	.003257
132.0	.010651	.000041	.000492	.003377
133.0	.012295	.000043	.000511	.003496
134.0	.014097	.000045	.000530	.003614
135.0	.016059	.000047	.000550	.003730

BLOCKING PROBABILITIES FOR C = 150 A = 11

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
125.0	.003152	.000002	.000039	.000403
126.0	.003844	.000002	.000042	.000425
127.0	.004649	.000002	.000044	.000447
128.0	.005574	.000003	.000046	.000470
129.0	.006630	.000003	.000049	.000493
130.0	.007823	.000003	.000052	.000517
131.0	.009162	.000003	.000054	.000540
132.0	.010651	.000003	.000057	.000564
133.0	.012295	.000003	.000059	.000587
134.0	.014097	.000003	.000062	.000611
135.0	.016059	.000004	.000064	.000634

BLOCKING PROBABILITIES FOR C = 150 A = 12

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
125.0	.003152	.000000	.000003	.000051
126.0	.003844	.000000	.000004	.000054
127.0	.004649	.000000	.000004	.000057
128.0	.005574	.000000	.000004	.000061
129.0	.006630	.000000	.000004	.000064
130.0	.007823	.000000	.000005	.000067
131.0	.009162	.000000	.000005	.000071
132.0	.010651	.000000	.000005	.000074
133.0	.012295	.000000	.000005	.000078
134.0	.014097	.000000	.000006	.000082
135.0	.016059	.000000	.000006	.000085

BLOCKING PROBABILITIES FOR C = 160 A = 9

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
135.0	.003607	.000523	.003993	.018114
136.0	.004340	.000546	.004145	.018[illegible]
137.0	.005179	.000569	.004297	.019267
138.0	.006135	.000592	.004449	.019840
139.0	.007213	.000615	.004602	.020410
140.0	.008420	.000638	.004754	.020975
141.0	.009762	.000661	.004905	.021532
142.0	.011243	.000684	.005054	.022082
143.0	.012866	.000707	.005202	.022622
144.0	.014634	.000729	.005347	.023152
145.0	.016547	.000752	.005490	.023670

BLOCKING PROBABILITIES FOR C = 160 A = 10

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
135.0	.003607	.000054	.000621	.004123
136.0	.004340	.000056	.000649	.004289
137.0	.005179	.000059	.000678	.004456
138.0	.006135	.000062	.000707	.004624
139.0	.007213	.000065	.000736	.004792
140.0	.008420	.000068	.000766	.004959
141.0	.009762	.000071	.000795	.005126
142.0	.011243	.000073	.000824	.005291
143.0	.012866	.000076	.000853	.005455
144.0	.014634	.000079	.000882	.005616
145.0	.016547	.000082	.000910	.005774

BLOCKING PROBABILITIES FOR C = 160 A = 11

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
135.0	.003607	.000004	.000075	.000723
136.0	.004340	.000005	.000079	.000758
137.0	.005179	.000005	.000083	.000793
138.0	.006135	.000005	.000087	.000829
139.0	.007213	.000005	.000091	.000865
140.0	.008420	.000006	.000096	.000901
141.0	.009762	.000006	.000100	.000937
142.0	011243	.000006	.000104	.000974
143.0	012866	000006	.000108	.001009
144.0	014634	.000007	000113	.001045
145.0	.016547	.000007	.000117	.001080

BLOCKING PROBABILITIES FOR C = 160 A = 12

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
135.0	.003607	.000000	.000007	.000100
136.0	.004340	.000000	.000008	.000106
137.0	.005179	.000000	.000008	.000112
138.0	.006135	.000000	.000009	.000117
139.0	.007213	.000000	.000009	.000123
140.0	.008420	.000000	.000010	.000129
141.0	.009762	.000000	.000010	.000135
142.0	.011243	.000000	.000011	.000141
143.0	.012866	.000000	.000011	.000147
144.0	.014634	.000000	.000011	.000153
145.0	.016547	.000000	.000012	.000159

BLOCKING PROBABILITIES FOR C = 160 A = 13

LOAD	OUTER	INNER(28)	INNER(35)	INNER(42)
135.0	.003607	.000000	.000001	.000011
136.0	.004340	.000000	.000001	.000012
137.0	.005179	.000000	.000001	.000013
138.0	.006135	.000000	.000001	.000013
139.0	.007213	.000000	.000001	.000014
140.0	.008420	.000000	.000001	.000015
141.0	.009762	.000000	.000001	.000016
142.0	.011243	.000000	.000001	.000017
143.0	.012866	.000000	.000001	.000017
144.0	.014634	.000000	.000001	.000018
145.0	.016547	.000000	.000001	.000019

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